

SOIL AND WATER RESOURCE CHARACTERISTICS IN RELATION TO LAND DISPOSAL OF URBAN SOLID WASTES

BY

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Mr. K. JEEVAN RAO, has satisfactorily prosecuted the course of research and that the thesis entitled SOIL AND WATER RESOURCE CHARACTERISTICS IN RELATION TO LAND DISPOSAL OF URBAN SOLID WASTES, submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

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This is to certify that the thesis entitled **SOIL AND WATER RESOURCE CHARACTERISTICS IN RELATION TO LAND DISPOSAL OF URBAN SOLID WASTES** submitted in partial fulfilment of the requirements of the degree of 'Doctor of Philosophy' in Agriculture of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr. K. JEEVAN RAO**, under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. All assistance and help during the course of the investigations have been duly acknowledged by the author of the thesis.

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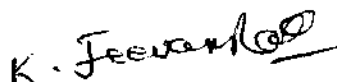
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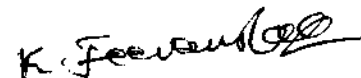
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(K. JEEVAN RAO)

DECLARATION

I, K. JEEVAN RAO, hereby declare that the thesis entitled SOIL AND WATER RESOURCE CHARACTERISTICS IN RELATION TO LAND DISPOSAL OF URBAN SOLID WASTES, submitted to Andhra Pradesh Agricultural University for the Degree of DOCTOR OF PHILOSOPHY IN AGRICULTURE is the result of the original research work done by me. I also declare that my material contained in the thesis has not been published earlier.

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ABSTRACT

The urban solid wastes generated in Hyderabad city are being disposed off by landfill at three landfill sites viz., Amberpet, Golkonda and Autonagar and also utilized directly by the farmers as a manure. The impact of disposal of urban solid wastes generated in Hyderabad as either landfill or as a manure, on soil properties and ground and surface water quality was investigated.

The solid wastes generated in Hyderabad were highly heterogenous and contained comparatively less of plastics, paper, metal and rubber as compared to the waste characteristics reported in other developed countries. The content of gravel, soil and dust were, however, more in the wastes. The wastes were alkaline in pH and the organic carbon content ranged from 3.4 to 6.3 per cent. With the COD ranging from 89.0 to 168.0 mg g⁻¹. The content of soluble salts was also high and variable and contained heavy metals and micronutrients.

The characteristics of soil profiles under the urban waste dumps in one of the landfill sites (Amberpet) were studied. The textural characteristics of the soil at various depths were modified due to solid waste overlay. The other important soil characteristics, pH, EC, organic carbon, CEC, exchangeable cations, total and available nutrients content, water soluble ions, ESP, total heavy metals and DTPA-extractable trace metals increased substantially but the total micronutrients decreased as compared to control.

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A bioassay procedure evolved to assess the impact of waste disposal on soil profile characteristics clearly demonstrated that the seeds of Italian millet failed to germinate in soils of some depths in soil profiles where USW were disposed. This was mainly due to high EC and ESP of soils.

Analysis of surface runoff water samples at the Amberpet landfill site for pollution causing constituents have shown that the water quality is altered significantly due to the land disposal of USW. The water was fit for irrigation and not suitable for drinking purpose by animals and man. The quality of underground water (Bore and open wells) sources was assessed at both Amberpet and Golkonda landfill sites. The groundwaters at both the landfill sites were polluted and are unfit for human consumption and domestic use but could be used for irrigation only.

Land application of urban solid wastes upto 33 t ha⁻¹ benefited the maize crop but not at 44 t ha⁻¹. The uptake of Pb, Ni and Co by maize increased due to USW addition but not with FYM and soil characteristics like pH, EC, total and DTPA-extractable trace metals increased due to USW but not to any significant extent with FYM.

The effect of continuous application of fresh USW on soil properties and uptake of microelements by some crops in farmers' fields showed that the soil properties like texture, colour, pH, EC, total and extractable micro-elements increased substantially and some of them attained toxic limits. Several crop plants absorbed the micro-elements in increasing concentration and some of these (Zn, Cu, Pb and Ni) were absorbed actively by the plants which indicates the possible pollution threat with their entry in the food chain. Chromium and Cadmium were, however, not detected, but lead which was absorbed tended to remain in the roots and was not translocated to edible plant parts like fruits and grains. The concentration of trace elements in plants varied widely depending on plant species and plant parts.

LIST OF ACRONYMS AND ABBREVIATIONS

AFW	: Autonagar fresh waste
Ag NO ₃	: silver nitrate
Al	: aluminium
APHA	: American Public Health Association
ASW	: Amberpet stabilized waste
B	: boron
BaCl ₂	: barium chloride
BOD	: biochemical oxygen demand
btu/lb	: British thermal unit per pound
C	: carbon
°C	: degree centigrade
Ca	: calcium
CaCl ₂	: calcium chloride
CaCO ₃	: calcium carbonate
Cd	: cadmium
Cd/Zn	: cadmium zinc ratio
CEC	: cation exchange capacity
Cl	: chloride
cm	: centimeter
Cmol (p+)kg ⁻¹ soil	: centimole per kilogram (cations)
C/N	: carbon nitrogen ratio
Co	: cobalt
CO ₂	: carbondioxide
CO ₃	: carbonate
COD	: chemical oxygen demand

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Cr	: chromium
Cu	: copper
DAS	: days after sowing
DO	: dissolved oxygen
$d S m^{-1}$	: deci siemen per meter
DTPA	: diethylene triamine penta acetic acid
dw	: dry weight
EC	: electrical conductivity
EDTA	: ethylenediaminetetraacetate
ESP	: exchangeable sodium percentage
F	: fluoride
Fe	: iron
Fig.	: figure
FUSW	: fresh urban solid waste
FYM	: farmyard manure
g	: gram
$g dish^{-1}$	: gram per dish
GFW	: Golkonda fresh waste
GSW	: Golkonda stabilized waste
H	: hydrogen
ha	: hectare
HCl	: hydrochloric acid
$HClO_4$	: perchloric acid
HCO_3	: bicarbonate
HNO_3	: nitric acid
H_2SO_4	: sulphuric acid

ICMR	: Indian Council of Medical Research Institution
ISI	: Indian Standards Institution
K	: potassium
$K_2Cr_2O_7$	: potassium dichromate
kg	: kilogram
$kg\ ha^{-1}$	: kilogram per hectare
K_2O	: potash
L	: liter
l	: loam
ls	: loamy sand
m	: meter
m^3	: cubic meter
Mg	: magnesium
mg	: milligram
$mg\ g^{-1}$	: milligram per gram
$mg\ kg^{-1}$	: milligram per kilogram
$mg\ l^{-1}$	: milligram per litre
ml	: milliliter
mm	: millimeter
Mn	: manganese
MO-Alkalinity	: methyl orange alkalinity
MPN	: most probable number
MSW	: municipal solid waste
N	: nitrogen
Na	: sodium
ND	: not detected

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NEERI	: National Environmental Engineering Research Institute
NH ₄	: ammonia
NH ₄ OAc	: ammonium acetate
Ni	: nickel
NO ₃	: nitrate
NTU	: nephelometric turbidity unit
O	: oxygen
OC	: organic carbon
OM	: organic matter
P	: phosphorus
P-Alkalinity	: phenolphthalein alkalinity
Pb	: lead
P ₂ O ₅	: phosphorus pentaoxide
PO ₄	: phosphate
ppm	: parts per million
S	: sulphur
s	: sand
scl	: sandy clay loam
Se	: selenium
sl	: sandy loam
SO ₄	: sulphate
Sm ⁻¹	: siemen per meter
Sn	: tin
t	: tonne
TA	: total alkalinity
t acre ⁻¹	: tonne per acre

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TDS	: total dissolved solids
TEA	: triethanolamine
TH	: total Hardness
t ha ⁻¹	: tonne per hectare
TS	: total solids
TSS	: total suspended solids
USW	: urban solid waste
viz.	: namely
WHO	: World Health Organisation
Zn	: zinc
%	: per cent
>	: greater
<	: less
ug	: microgram
u S m ⁻¹	: microsiemen per meter

INTRODUCTION

CHAPTER - I

INTRODUCTION

Waste generation, either in solid or liquid form, is a gift of civilization. In large urban communities, huge quantities of solid wastes are generated due to normal human activity both in homes and industries. The wastes generated pose serious problems of collection, transportation and ultimate disposal. Several methodologies for urban solid wastes (USW) disposal have been advocated but the fact remains that the most common disposal method adopted is by landfill. Alternatively, fresh urban solid wastes are also being disposed directly on agricultural land or pretreated to obtain a 'compost' and then applied to land for cultivation of crops.

Hyderabad is a major Indian city with a population of more than five million and the extent of solid waste generated from the city is estimated to be 1800 to 2000 t day⁻¹. The solid wastes generated due to domestic and industrial activity are highly variable heterogeneous in respect of their physical characteristics, chemical and biological properties. The solid wastes generated in Hyderabad metropolitan area are majorly disposed of as landfill in low lying areas and also directly applied to agricultural lands.

In view of the magnitude of solid waste generation, in large urban communities the problems of their disposal have also been many. The land fill sites presently in use occupy large land areas in and around Hyderabad and have already received a few million tons of wastes over the past two or three decades. The disposal of such huge volume of wastes may pose serious soil, water and atmospheric pollution problems in the adjacent areas. There is a distinct possibility that the soil, ground and surface water bodies at the landfill site or the adjoining areas are subjected to several types of pollution. In addition, direct application of fresh urban solid wastes is a common agricultural practice around Hyderabad city. If the fresh wastes are continuously applied on agricultural land for cultivation of crops, problem of pollution of soil, crop plants, ground and surface waters may emerge gradually. Alternatively, if problems of such pollution are not of any serious nature the urban solid wastes can be considered as a very valuable resource for use as manure on agricultural land.

To evaluate the impact of disposal of USW generated in Hyderabad either as landfill or by direct application to land, on soil characteristics, pollution hazards and manurial value of the wastes, the present studies were conducted with the following objectives:

- * Characterisation of urban solid wastes of Hyderabad
- * Studies on soil and water characteristics at landfill site
- * Evaluation of the accumulation of inhibitory substances in soil profiles under USW dumps by a bioassay
- * To evaluate the response and uptake of trace elements by maize to applications of USW and FYM in a pot culture study
- * To study the properties of soils as affected by the application of raw USW with special reference to build up of micronutrients and heavy metals and development of salinity or alkali hazards in the farmers fields around Hyderabad city
- * To study the uptake of micronutrients and heavy metals by plants grown on soils treated with USW in the farmers' fields around Hyderabad and their possible impact on the food chain

The results of these investigations are presented and discussed in the thesis.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Waste production has been a part of human activity since time immemorial. Since the eco-system cannot absorb them in the natural course, the accumulation of such wastes poses a serious environmental problem. In recent times, it is realised that the waste accumulation may seriously affect the stability of the biosphere.

During the last three decades, it is being increasingly realized that the resources of the earth supporting the human activity are limited. In order to maintain a stable economic growth and a reasonably high standard of living, it is essential that we use the limited available resources carefully and also evolve, at the same time, suitable technologies for the recycling of organic wastes to save both non-renewable resources and energy (Gaur, 1979).

2.1 SOLID WASTES

Solid wastes may be defined as "useless, unwanted or discarded materials that arise from human activities and are not free flowing" (WHO Expert Committee, 1971). The extraction and processing of industrial raw materials produce for greater quantities

of solid waste, than those generated from homes. In India, a comprehensive status report on utilization and recycling of wastes was prepared in 1975 by the National Committee on Science and Technology of the Government of India (Tiwari and Patel, 1990).

2.1.1 Solid waste generation in India

In India, the total urban population of 240 million produces approximately 29 million tonnes of solid refuse annually at an average of 0.33 kg per capita per day (NEERI, 1983).

The increasing cost of chemical fertilizers and their limited availability, coupled with the concern for efficient utilization of energy and natural resources have generated an interest in alternative uses and utilization of urban and industrial wastes. Golueke (1977) claimed that use of organic fertilizer instead of chemical fertilizer can result in a two-thirds energy saving.

2.1.2 Types of solid wastes

Solid wastes generated in areas of human habitation can be categorised mainly into two types viz., urban solid wastes and industrial solid wastes. The methods proposed for disposal of urban solid wastes are - sanitary landfill, composting, incineration, pyrolysis

and recycling of nutrients through direct land application. Out of these alternatives, generally, sanitary landfill, and to a limited extent composting are practiced in India. Direct application of fresh USW to land for cultivation of crops is also a common practices in areas nearer to the large cities.)

2.1.3 Solid waste disposal methods

Presently, most of the waste is disposed in low lying areas without taking proper precautions. This is observed to result in breeding of rodents, flies and other domestic pests and also tends to pollute the surface as well as ground waters. Hence, it is necessary to adopt sanitary landfilling techniques so that such problems are avoided.

2.1.3.1 Sanitary landfill: Of all the methods employed in solid waste processing and disposal the one method which is a complete, cost efficient and not energy or capital intensive is the sanitary landfill. Sanitary landfill or more accurately the transport and burying of solid waste in a controlled and compacted manner is the most widely used method of waste disposal. Michaels (1966) estimated that landfill disposal method is used to dispose in excess of 90 per cent of all solid waste generated in USA. One reason for this wide acceptance is the relatively low cost of the method and the fact that incineration, composting and resource recovery all

require land for the disposal of varying quantities of residual material which is, however, less in volume than the original raw waste. The energy requirement for these methods is also much more than what is required for disposal by landfill.

From the view point of materials handling, a sanitary landfill can be considered a complete method of disposal. Precipitation falling on the landfill can leach a combination of organic and inorganic materials from the landfill system. Any percolating water in excess of field capacity will drain through the waste and as this leachate moves vertically, it continues to solubilize additional materials. Organic matter initially insoluble, may be solubilized through biological activity and accounts for most of the organic matter leached from the landfill.

Sanitary landfilling is the act of operating a land solid waste disposal site. There are many types of sanitary landfills including "ravine landfills", "wet landfills", "industrial waste landfills" and "unrestricted landfills".

2.1.3.2 Landfill stabilization: At present the time required for landfill stabilization (minimal biological activity) is not known. Most sanitary landfills in India are less than 30 years old and no attempts have been

made to establish stabilization criteria. The complexity of the fill material makes isolation of all but a few reactions very difficult. The moisture, temperature and composition of refuse are the crucial factors determining the rate of decomposition.

2.1.3.3 Composting: Composting involves the biological stabilization of solid matter either under aerobic or partially aerobic conditions. The end product of composting is an organic material which would have beneficial value as a soil conditioner or plant mulch.

Modern methods of composting parallel the historical development of composting techniques. The most common solid waste processing methods practiced in India is the continuous aerobic type and are generally mesophilic i.e., the dominant organisms are most efficient at temperatures typically around in 30-37°C.

In addition to producing a modified solid waste material, which can be useful in land reclamation, composting does yield a volume reduction of about 40-60 per cent of the compostable solid waste (Gotass, 1962).

2.2 CHARACTERISTICS OF URBAN SOLID WASTES

A survey of literature reveals that very little information is available on the extent and nature of wastes generated in India (NEERI, 1970; Bhide et al.; 1972; Vimal and Talashilkar, 1984; Mall and Upadhyay,

1988; Jain and Sharma, 1988; Mitra and Pandey, 1989; Tiwari and Patel, 1990).

2.2.1 Physical and chemical Characteristics

Refuse is a very general term used to include all types of unwanted solid and semi solid wastes other than excreta produced in urban and rural environment.

The city refuse is normally a combination of garbage, rubbish and street sweepings containing soil and ash. Wastes exhibit different characteristics depending upon the nature and occupation of contributing population and their living styles.

The organic fraction of refuse normally starts decomposing either aerobically or anaerobically if it is not collected and disposed immediately. A knowledge of nature of the organic fraction in urban solid wastes help in the precaution that will have to be taken during its collection and disposal. The physical characteristics of the wastes provide an idea about the constituents of the waste and assist in selecting a suitable method for its disposal. The chemical characteristics of the waste normally help in finding out the possible products that can be obtained during processing of the wastes for disposal and the likely problem that may have to be encountered as in the designing of a suitable process for waste treatment.

Seasonal variations in waste characteristics are yet another dimension, which complicates the disposal problems. The National Environmental Engineering Research Institute (NEERI), Nagpur, India, have surveyed and collected information on the quality and quantity of refuse generated in different seasons and with different contributing population ranges in the major cities of the country. A knowledge of variation in quantities will be very useful in planning the operation and maintenance of a solid waste collection and disposal system.

In cities and large urban centres, the composition of refuse is affected by the waste products from industries, cutting from lawns, gardens, avenue trees, street sweepings, domestic garbage and wastes discarded from commercial establishment. The method and frequency of refuse removal also affect the composition of urban solid wastes. It is difficult to compare the characteristics of solid wastes of a urban community with others on account of general scarcity of accurate, reliable and complete measurement and record on comparable basis, difference in collection and disposal practice, geographical situation, capacity of land, seasonal variation in waste production and other factors such as standard of living and economic conditions of the community (Bhide, 1984).

In majority of Indian cities, the per capita production of refuse ranges from 0.15 to 0.35 kg day⁻¹. The overall average solid waste generation percapita is estimated at 0.33 kg day⁻¹ as at the present (Bhide, 1984). The data on percapita production of refuse quantity from other countries is found to vary from 0.5 kg to 1.5 kg day⁻¹. The maximum production of 2.5 kg day⁻¹ is reported from USA. Normally the percapita value does not change appreciably in locations with comparable climatic conditions and living and food habits. But the change in standard of living and density of population per unit area has a perceivable influence on the quantity and quality of solid wastes generated from urban areas.

The weight-volume relationship of solid wastes generated in Indian cities is higher when compared with refuse of western countries. In many Indian cities the density of urban refuse ranges between 330 to 560 kg m³. In a large majority of Indian cities, the volatile or decomposable matter content was found to vary between 10-30 per cent. No specific trend in the volumes of nitrogen, potash and phosphorus was observed in refuse from various parts of the country in different seasons (Bhide, 1984).

The presence of ash and fine earth in larger proportions in the solid wastes generated in Indian

cities is due to a collection system where the street sweepings are also mixed with refuse. The ash and fine earth decrease with increase in population and their living standards, whereas the plastics and glass contents show a clear tendency of increase. The amount of plastics and glass present in Indian urban solid waste is quite negligible as compared to refuse from other countries because much of the recyclable materials like metal, plastics, paper, textiles and rubber are salvaged from the waste dumps or from the street bins from the garbage by a section of people who make a living out of this. Such salvaged materials are sold at specific collection centres which are a part of every large or small urban agglomeration in India.

The average physical constituents of refuse generated in Indian cities with a population of more than 2 million is - paper 7.07, rubber and leather 0.87, plastics 0.86, metals 1.03, glass 0.76, ash and fine earth 31.74, total compostable matter 41.69, miscellaneous matter 15.98 per cent by dry weight. The other constituents are: moisture 31.18, organic matter 27.57, organic carbon 15.32, nitrogen 0.58, phosphorus as P_2O_5 0.59, potash as K_2O 0.68 per cent, C/N ratio 26.23 and pH 7.68 (Bhide and Sundaresan, 1983). The compostable matter varied between 33 to 42 per cent.

Bhardwaj and Gaur (1985) reported that the Indian municipal refuse contains 0.5, 0.3 and 0.3 per cent nitrogen, phosphorus and potassium, respectively.

Radia Khatib et al. (1990) studied the municipal waste from Karachi, Pakistan and reported that it contained 89.5 per cent (dry basis) total recyclable material out of which plastics constitute 9.85, paper 10.1, glass 1.24, bones 1.85, metal 0.74, leather and rubber 0.2, organic vegetable matter 54.5 per cent. Approximately 4500 tonnes of garbage is produced daily in Karachi city. Here also, as in India, it is reported that many components of the refuse are salvaged for reuse.

Recycling of waste components is a well established practice in Europe and has gained worldwide acceptance. In USA, it is reported that approximately 27 per cent paper and 10 per cent glass are recycled. In the United Kingdom, 29 per cent paper and 12 per cent glass wastes, and in Japan, 48 per cent paper are recovered and used for recycling (Pollock, 1987).

Gupta et al. (1984) studied the characteristics of the Calcutta city waste composts for their physico-chemical properties and nutrient status. They reported that the composts were neutral to slightly alkaline in reaction containing high amount of silt and sand particles with 20 to 26 per cent moisture. Total

organic carbon ranged from 8.5 to 10.0 per cent. Total nitrogen content was 0.6 per cent. The available P varied from 326.0 to 370.0 ppm while available K ranged from 0.18 to 0.25 per cent. City waste composts were quite high in total Ca (3.16 to 4.50 per cent) in comparison to Na (0.30 to 0.38 per cent), K (1.68 to 2.75 per cent) and Mg (0.54 to 0.60 per cent). Water soluble and DTPA extractable micronutrient elements were present in optimum level except Zn and Fe. The concentration of Cd varied from 4.0 to 10.0 ppm.

Gupta et al. (1986) studied the nature and chemical composition of compost obtained from urban wastes of Calcutta. The compost was neutral to slightly alkaline in reaction with the pH varying from 7.5 to 8.1, conductivity 1.04 to 2.05 d S m^{-1} , organic carbon 7.2 to 7.8 per cent and available N 303.0 - 370.0 ppm, available P 360.0 - 380.0 ppm, available K 1870.0 - 2500.0 ppm, total N 0.63 to 0.69 per cent, total P 0.28 to 0.31 per cent, total K 1.67 to 2.79 per cent and available (DTPA extractable) micronutrients ranged from Fe 84.0 to 90.0 ppm, Zn 144.0 to 150.0 ppm, Cu 24.0 to 30.0 ppm and Mn 30.0 to 38.4 ppm.

Ramachandran and D'Souza (1990) found that the characteristics of compost prepared from Bombay city wastes were pH 7.7, organic carbon 10.4 per cent, total chromium 51.0 ppm and available chromium only in traces,

total and available Mn content as 622 and 45 ppm, respectively.

Bhide (1984) has provided data on the source of heavy metals in different USW components which is detailed in Table 1.

Patel and Tiwari (1990) conducted a survey on the physical composition and some physico-chemical characteristics of urban solid wastes in Rourkela. The overall average values were reported as construction material 41.5, dust and cinder 47.7, scrap metal 3.4, paper and cardboard 1.1, glass 0.8, broken china 1.2, mica 1.0, plastics and polythene 1.0 and miscellaneous 2.3 per cent. The overall average results of the chemical characteristics were pH 7.1, moisture content 41.4, water soluble part 51.0, organic matter 42.5, nitrogen (N) 0.59, phosphorus (P) 0.74, carbon (C) 24.6 per cent and C/N ratio 41.3. The ultimate elemental analysis of physical components of urban solid waste reported by Liptak (1974) is provided in Table 2.

Studies on urban waste characteristics in India has so far been directed by and large to understand the waste characteristics in relation to its suitability for composting and the characteristics of composts, thus, obtained. Use of urban waste composts in crop production has also been investigated. Studies pertaining to

Table 1 : Heavy metal source in urban solid waste components

Source	Cd	Cr	Cu	Pb	Zn
Mining and Metallurgy	x	x	x	x	x
Paints and Dyes	x	x	x	x	-
Pesticides	-	-	-	x	x
Electrical and Electronic	-	x	x	x	-
Printing and Duplicating	x	x	x	x	-
Electro Plating and Metal Finishing	x	x	x	-	-
Chemical Manufacturing	-	x	x	-	-
Explosives	-	-	x	x	-
Rubber and Plastics	-	-	-	-	x
Batteries	x	-	-	x	x
Textiles	x	x	x	-	-
Petroleum and Coal	x	-	-	x	-
Leather	-	x	-	-	-

x = Present
- = Not present

Source : Bhide (1984)

Table 2 : Ultimate elemental analysis of municipal solid wastes

Solid waste components	-----															Fixed C dry basis	Heating value btu/lb dry basis
	C	H	O	N	Ash	S	Fe	Al	Cu	Zn	Pb	Sn	P	Cl	Se		

Metal	4.5	0.6	4.3	0.05	90.5	0.01	77.3	20.1	2.0	-	0.02	0.6	0.03	-	-	0.5	740
Paper	45.4	6.1	42.1	0.3	6.0	0.12	-	-	-	-	-	-	-	-	Tr	11.3	7930
Plastics	59.8	8.3	19.0	1.0	11.6	0.3	-	-	-	-	-	0.01	6.0	-	-	5.1	11500
Leather and rubber	-	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	6.4	10175
Textiles	16.2	6.4	41.8	2.2	3.2	0.2	-	-	-	-	-	0.03	-	-	-	3.9	8030
Wood	48.0	6.0	42.4	0.3	2.9	0.11	-	-	-	-	-	-	0.05	-	-	14.1	8400
Food waste	41.7	5.8	27.6	2.8	21.9	0.25	-	-	-	-	-	-	0.24	-	-	5.3	8590
Yard waste	19.2	6.5	36.1	2.9	5.0	0.35	-	-	-	-	-	-	0.04	-	-	19.3	7300
Glass	0.52	0.07	0.36	0.03	99.02	-	-	-	-	-	-	-	-	-	-	0.4	65
Misc.	13.0	2.0	12.0	3.00	70.00	-	-	-	-	-	-	-	-	-	-	-	-

* Excluded Phosphorus present as CaPO_4 Source: (Liptak, 1974)

waste characteristics in relation to soil pollution and ground and surface water characteristics are however, very much limited.

2.3 POLLUTION HAZARDS FROM URBAN SOLID WASTES

Improper and unscientific disposal of urban solid wastes may pollute air, water and soil in several ways.

2.3.1 Atmospheric pollution

One of the critical public health hazard from a sanitary landfill is due to the gases emanating from the decomposition of the organic matter under partially anaerobic conditions. Of the gases generated (CO_2 , CO , CH_4 , H_2 and H_2S), CH_4 and H_2 can be explosive. CO_2 can cause acidic reactions when dissolved in water and can be the cause for corrosion problems. Hydrogen sulphide is a known corrosive, malodorous and if produced in high quantity can be irritating and toxic to man and animals. Gases are on record in which methane has escaped from landfills and caused severe damage. Horizontal movement and distribution of the gases in dangerous concentrations beyond the confines of the fill upto to 300 meters away has been reported (USDHEW, 1969 and Rodney, 1968).

2.3.2 Water pollution

The water pollution due to urban solid wastes is reviewed here covering the following two aspects:

- * Water quality criteria
- * Water pollution due to solid wastes

2.3.2.1 Water quality criteria: Water quality is now a serious cause of concern and many national and international organisations and agencies are devoting their attention to study the cause of water pollution and find solutions for the supply of safe drinking water to the human populations, domestic animals and wild life.

Distribution of Water: Earth is a water rich planet. The total available water on the basis of current estimate is $1.4 \times 10^9 \text{ km}^3$. Ocean water accounts for 97.3 per cent and remaining 2.7 per cent is potable water. The potable water consists of polar ice-caps and glaciers 77.2 per cent, ground water and soil moisture 22.4 per cent, lakes and swamps, 0.35 per cent, atmosphere 0.4 per cent and streams less than 0.01 per cent. In other words, nearly 90 per cent of fresh water is stored in ice-caps, glaciers and deep (750 metres) ground water and, therefore, is not easily accessible. It is surface water in rivers, streams and lakes amounting to less than 0.5 per cent of available fresh

water, that constitutes the basic available supply (Nanoti and Hasan, 1984).

The annual rainfall in India is just over $3.7 \times 10^{12} \text{ m}^3$ of water of this $1.25 \times 10^{12} \text{ m}^3$ is lost by evaporation and roughly $0.85 \times 10^{12} \text{ m}^3$ seeps into the soil, leaving $1.6 \times 10^{12} \text{ m}^3$ to flow into the river system. It has been estimated that only $0.5 \times 10^{12} \text{ m}^3$ can be used for irrigation (Nanoti and Hasan, 1984). Of $0.85 \times 10^{12} \text{ m}^3$ that seeps into the soil annually, $0.4 \times 10^{12} \text{ m}^3$ remains in top layers and contributes to soil moisture which is essential for growth of vegetation. The remaining percolates into the porous soil strata and represents the recharge of underground water (Nanoti and Hasan 1984).

Giving due regard to the conditions prevailing in India relating to the provision of safe drinking water supplies, the progress of the schemes under various National and State development programmes and the need for prescribing standards of bacteriological and chemical quality which safeguard the health of the consumers and at the same time liberal enough to permit the acceptance of supplies which are satisfactory as regards their sanitary conditions, Indian Council of Medical Research (ICMR), Ministry of Health, Government of India have prescribed the standards (1975) for drinking water.

World Health Organisation (1984) prescribed guidelines for the water quality. These guidelines have been divided into two groups :

- * Aesthetic/organoleptic guidelines, and
- * Health related guidelines

Aesthetic/organoleptic guidelines: The presence of such substances above the suggested limit changes the palatability and appearance of drinking water. Their influence upon the quality of drinking water is oriented more towards the sensory than the toxic aspect. These include both physical and chemical characteristics of water.

Physical characteristics: They include (i) transparency, which is determined, by the colour and turbidity imparted to water by material of vegetative origin, such as tannins, humic acids, peat materials, plankton or weeds. Metal ions, e.g., manganese, copper and chromium, may also impart colour; (ii) temperature, which influences rate of biochemical processes resulting in change of contents of organic and mineral substances in some cases; (iii) electrical conductivity, which is caused due to the presence of electrolytes which dissociate into cations and anions, (iv) pH, an important index of hydrogen ion (H^+) activity and is the resulting value of the acid-base interaction of a number

of mineral and organic components in water and (v) taste and odour associated with the presence of decaying vegetation, some inorganic and organic substances decomposed by variety of microorganisms.

Chemical characteristics: These are the most important indices, which characterise the quality of water and enable to (i) classify the water based on chemical composition, (ii) evaluate the need to provide water bodies with nourishing additives for the development of aquatic organisms (iii) characterize the degree and nature of pollution and (iv) record cases of sharp changes in polluting substances and pinpoint main source of pollution.

Acidity: Acidity of water is its quantitative capacity to react with a strong base till neutralization to a pre-decided pH. Acidity is a measure of an aggregate property of water and can be interpreted in terms of specific substances when the chemical composition of the samples is known. Acidity contributes to corrosiveness and influence biological processes.

Alkalinity: Alkalinity of water is its quantitative capacity to react with a strong acid to a pre-designated pH. Alkalinity is essentially a function of carbonate, bicarbonate and hydroxide ion contents. Alkalinity perse is not considered detrimental to human beings. But it is generally associated with high pH

values, hardness and excessive quantities of dissolved salts, all of which may affect the organoleptic character of water.

Hardness: Waters are conventionally classified as hard or soft depending on the amount of soap consumed to produce lather, being less with soft water. Current practice is to define total hardness as the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in mg l^{-1} . Hard water have no apparent harmful effects on health of the consumers.

Chloride: Chloride concentration is generally low in natural waters. Levels in unpolluted water are often less than 10 mg l^{-1} . High concentration of chloride may impart undesirable taste to water. Taste threshold for chloride associated with either sodium, potassium or calcium significantly varies with concentration from 200 to 300 mg l^{-1} as chloride. The guide limit as per the standards prescribed by WHO (1984) for chloride in drinking water is 250 mg l^{-1} based on taste consideration. Chlorides in drinking water are not generally harmful to human beings, although for people suffering from diseases of heart or kidney, high chloride in drinking water is considered as unsafe.

Sulphate: In most fresh waters, sulphates are low in concentration. Ingestion of water containing

excessive concentration of sulphate can have a laxative effect, which is enhanced when sulphate is consumed in combination with magnesium. The limits of sulphate are not based on test or physiological effects other than laxative effect. The guide limit of sulphate is 400 mg l^{-1} .

Dissolved solids: The dissolved solids in natural water consist mainly of bicarbonates, chlorides, sulphates and possibly fluorides and nitrates of calcium, magnesium, sodium and potassium with traces of iron and manganese. The palatability of drinking water with total dissolved solids (TDS) level of less than 600 mg l^{-1} is generally considered to be good. Drinking water with higher TDS of more than 1200 mg l^{-1} becomes increasingly unpalatable. The guide limit for TDS in drinking water is 1000 mg l^{-1} .

Iron and Manganese: Both iron and manganese are objectionable constituents in water supplies for domestic and industrial uses. The taste imparted to water may be described as bitter and astringent. The concentration of iron in well aerated and settled water is seldom high but under reducing conditions and, in the absence of sulphide and carbonate, higher concentrations of soluble ferrous iron may be found in ground lake or reservoir water.

Iron at levels above 0.3 mg l^{-1} and manganese at levels exceeding 0.15 mg l^{-1} stains laundry and plumbing fixtures. The guide limit of iron in drinking water is 0.3 mg l^{-1} ; and that of manganese is 0.1 mg l^{-1} .

Health related guidelines

These are for substances whose presence above the limit causes ill effects on health of humans and animals.

Fluoride: Traces of fluoride occur in many waters but higher concentrations tend to be associated with ground water sources. Generally, water contains less than 1 mg l^{-1} of fluoride but may occasionally be as high as 35 mg l^{-1} . Fluoride reduces the solubility of the enamel of the teeth, thereby, providing protection against dental cavities. The incidence of cavities decreases as the concentration of fluoride increases to about 1 mg l^{-1} . Excessive fluoride in drinking water supplies, however, produces dental fluorosis which increases with increasing fluoride concentration above the recommended levels. Other effects from excessively high intake levels are (a) bone changes when water containing $8\text{--}20 \text{ mg l}^{-1}$ is consumed over a long period of time and (b) crippling fluorosis when 20 mg or more fluoride from all dietary sources including water is

consumed per day for 20 or more years. It has been recommended that 1 mg l^{-1} fluoride in water is a safe level.

Nitrate and Nitrite: Both nitrate and nitrite are produced by bacterial oxidation of organic nitrogen. They can also enter water bodies as surface run-off as a result of usage of fertilizer, decomposing organic residues, domestic effluents, sewage sludge disposed on land, industrial discharges, leachate from refuse dumps and atmospheric washout. World-wide, levels of nitrate in water are typically below 5 mg l^{-1} nitrate-N but levels exceeding 100 mg l^{-1} are also recorded. Studies have revealed levels of nitrate in the range of 20 to over 200 mg l^{-1} nitrate-N. Conventional treatments do not modify the levels of nitrate to any appreciable extent.

In some circumstances, nitrates have been shown to be a health hazard to infants and possibly elder children, if the concentration in drinking water is greater than 45 mg l^{-1} as (NO_3) because, after reduction to NITRITE in the circulatory system, they may cause methemoglobinemia. Quality criterion for drinking water is 10 mg l^{-1} nitrate-N.

Arsenic: Arsenic generally occurs in water as inorganic compounds of tri- and pentavalent arsenic and organic arsenic. Water supplies generally contain low

(below 10 ug l^{-1}) levels of arsenic. Inorganic arsenic is more toxic than organic arsenic which when in trivalent form is more hazardous than pentavalent form. Intake of arsenic at higher levels through water is reported to severely impair gastrointestinal tract, nervous system, respiratory tract, muscular tissues, mucous membranes of the eyes, nose, larynx and skin. Neurological disorder and even malignant tumors in vital organs are also reported on long exposure. Quality criterion limit for potable water is 50 ug l^{-1} .

Cadmium: Drinking water normally contains very small amount of cadmium. There have been no reports of adverse effects from these low levels of cadmium on human and animal health. Quality criterion for potable water is 10 ug l^{-1} .

Chromium: Levels of chromium in water are usually low due to its poor solubility. It generally exists as trivalent chromium (Cr^{3+}) and hexavalent chromium (Cr^{6+}). Trivalent chromium rarely occurs in drinking water and is considered practically non-toxic. It is assumed that most water-borne chromium is in the hexavalent form which in high doses has been implicated as the cause of cancer of the digestive tract in man. Quality criterion for drinking water is 50 ug l^{-1} which incorporates a reasonable safety factor to avoid any hazard to human health.

Lead: Lead content of lake and river waters, world-wide, has been estimated to range from 1.0 to 10.0 $\mu\text{g l}^{-1}$. The levels in drinking water can be much higher due to leaching of lead from lead service pipes and household plumbing. However, the levels of lead in domestic tap water are well below 10-20 $\mu\text{g l}^{-1}$. In the same water supply area, there may be considerable house-to-house variation in the levels of lead in water because of differences such as, length of pipe, water usage patterns and type of deposit that build up in pipes. Symptoms of poisoning are associated with tiredness, lassitude, slight abdominal discomfort, irritability, anaemia and behavioural changes in children. Quality criterion for drinking water is 50 $\mu\text{g l}^{-1}$.

Nickel: Contamination of water bodies with the metal can arise from industrial discharge of effluent containing nickel compounds. Some nickel is removed by conventional water treatment and thus levels of nickel are generally low in consumer water supplies. Nickel is a relatively non-toxic element and normally nickel contamination is not considered as a serious problem. Quality criterion for drinking water is 100 $\mu\text{g l}^{-1}$.

Bacteriological quality: The following standards are recommended for the treated water (chlorinated or otherwise disinfected) distributed for human consumption.

Throughout any month, in 90 per cent of the samples examined, coliform bacteria should be absent in 100 ml of water sample. If coliforms are detected in any sample the numbers should be less than 10 per 100 ml.

2.3.2.2 Water pollution by sanitary landfill: The land disposal of solid wastes creates an important source of ground water pollution. A landfill may be defined as any land area serving as a depository of urban or municipal, solid waste. Most landfills throughout the world are simply refuse dumps; only a few if at all can be regarded as sanitary landfills, indicating that they were designed and constructed according to engineering specifications. Leachate from a landfill can pollute groundwater if water moves through the fill material. The possible sources of water include precipitation, surface water infiltration, percolating water from adjacent land and groundwater in contact with the fill. Urban refuse usually has a moisture content less than that of field capacity, therefore, leachate from a landfill can be minimized if water can be kept away from the landfill material. In a properly constructed sanitary landfill, any leachate generated can be controlled and prevented from polluting groundwater (Liptak, 1974).

The problem of pollution from landfills is greatest where high rainfall and shallow water table

occurs. Important pollutants frequently found in leachate include BOD, COD, iron, manganese, chloride, nitrate, hardness, and trace elements. Hardness, alkalinity and total dissolved solids are often increased, while generation of gases, such as methane, carbondioxide, ammonia and hydrogen sulfide are the other pollutants generated from landfills.

Polluted surface water that contributes to groundwater recharge become a sources of groundwater pollution. The recharge may occur naturally from a flowing stream.

During decomposition, organic wastes normally produce a leachate which dissolves a wide range of materials during its passage through the landfill. Such leachate may emerge from a landfill with a biological oxygen demand of over $20,000 \text{ mg l}^{-1}$, which is several folds stronger than that for raw sewage. Contamination of groundwater is common in areas where the rate of percolation through the soil is high.

The results of Olaniya and Saxena (1977) from studies on groundwater pollution by open refuse dumps at Jaipur (India) showed that the leachates from refuse had higher concentrations of organic carbon, iron and manganese coupled with high concentrations of dissolved solids. The leachate from tipped refuse was stronger

than sewage at the time of formation in terms of its nitrogen, phosphate and chloride contents and chemical oxygen demand. The total hardness, total dissolved solids, chloride, iron and chemical oxygen demand decreased in well waters as the distance from the refuse dumping grounds increased. Well water down to a distance of 50 m was highly polluted, but beyond a distance of about 200 m, the values remained more or less unchanged upto a distance of 450 m, indicating the distance upto which the quality of well water was affected by the leachate. The well waters were polluted and not suitable for drinking and domestic purposes.

Hoeks (1977) reported that in Netherlands, 50-60 per cent of the municipal refuse is dumped in or on the soil and the leachate from a waste disposal site is seriously polluted. Further they reported that the mobility of the pollutants in soil largely depends on chemical, physical and biological reactions.

Srinivasan (1977) investigated the contamination of groundwater by leachates from refuse dumps in Ontario, Canada. Analysis of surface and groundwater samples revealed that the contamination of groundwater was excessive. However, the presence above the aquifer of dry and silty soil, which absorbed a large proportion of contaminants, reduced pollution levels.

Murray et al. (1981) observed severe contamination of groundwater near sanitary landfill operations at Missouri, USA and concluded that the landfill to be the principal source of water pollution.

Tester and Harker (1982) investigated groundwater pollution at three domestic refuse sites and concluded that pollution plumes (zones) around domestic landfill are restricted and dilution is beneficial in ameliorating the effect of landfill leachate on groundwater quality.

Nicholson et al. (1983) studied groundwater pollution at a landfill in Ontario, Canada. The results revealed that calcium, sulphate and bicarbonate are the dominant cation and anions with maximum concentrations of 400, 2000 and 1200 mg l⁻¹ respectively. Beneath the landfill the most highly contaminated water in the aquifer had a total dissolved solids concentration of 4000 mg l⁻¹. Sulphate and iron are the inorganic constituents that exceeded the recommended limits for drinking water. The plume contained above background concentrations of dissolved zinc and manganese. No heavy metals or other hazardous inorganic trace elements accumulated above the maximum limits for drinking water. The plume contained total dissolved organic carbon that was above background level ranging from 30 mg l⁻¹

beneath the landfill to 5 mg l^{-1} near the front of the plume.

Movement of the pollutants to groundwater under a landfill can be predicted from local geohydrologic characteristics of the site (Sawhney and Raube, 1986).

✓✓ Gopal et al. (1991) investigated the extent of groundwater pollution in Kanpur city by solid wastes based on for various parameters such as pH, alkalinity, chloride ($1800\text{--}50 \text{ mg l}^{-1}$), sulphate $3000\text{--}600 \text{ mg l}^{-1}$) and BOD ($6000\text{--}100 \text{ mg l}^{-1}$) and hardness ($3000\text{--}600 \text{ mg l}^{-1}$) as initial and after 2.5 months, respectively. The leachate contain excessive pollutants upto one month from the time the refuse was exposed to leaching action. After two months, the values of all other pollutants were within limits, except hardness which continued to be quite high.

Heavy metals in urban solid waste landfill leachate: Problems connected with sanitary landfills used for municipal solid waste disposal included leachate generation. Unless leachate is properly collected and treated, surface and ground water may be polluted. The characteristics of leachates have been widely studied. They often contain a high concentration of organic matter and inorganic constituents including heavy metals.

Musmeci et al. (1985) reported that the heavy metal content of waste profiles are related to age of the wastes in the layers and in soil profiles, the metal releases are correlated to soil characteristics. Leachate samples collected from various landfills showed considerable quantitative variations, attributed to age and degree of stabilization.

Trace metals in ground water: The background values of trace metals in natural waters are extremely low. For example in sea water, the concentration of copper, zinc and lead are only 0.2, 0.05 and 0.005 ppm respectively. In normal river and ground waters the concentrations of Cu, Zn, Co, Ni, Cr, Ti, Mo and Pb are generally less than 10 ug l^{-1} . Unusually high concentrations of over 300 ppm of copper and zinc have been reported only in mine waters. Sokoloff (1960) stated that zinc content of 1 ppm is very common in water from chalcopyrite deposits and water from polymetallic deposits contain 0.2 to 1.0 ppm or more of zinc. Lead may be as high as 0.34 ppm in water from mines and shafts.

Hasan (1985) while reviewing the Indian scenario on heavy metals stated that the concentrations of Cd and Cu were comparatively low in well waters of all the Indian cities and zinc levels were observed to vary widely and were low as river water.

Coliforms as indicators of faecal pollution:

Bacteriological examination of water aims at the detection of bacteria particularly those which are normal inhabitants of human and animal digestive tracts. Generally, these faecal bacteria are present in large numbers in the excreta of man and animals, making the demonstration of exceedingly small quantities of pollution in water possible. They greatly outnumber the pathogenic bacteria, even in the faecal matter of patients suffering from enteric diseases and can survive longer in water than majority of the pathogens. Therefore, waters which are devoid of fecal bacteria like Escherichia coli and others in natural circumstances are considered to be probably free from disease producing organisms.

✓2.3.2.3 Ground water pollution: The degree and extent of pollution of groundwater depends primarily on the quantity and concentration of the pollutants and the porosity, permeability, hydraulic gradient, depth to the water table, storage capacity of the aquifer as well as the time factor.

When applied on the surface, the pollutants travel largely downward till they reach the water table and then move laterally. Shallow water table increases the risk of pollution. Generally, filtration through 3 to 5 metres of fine-grained soil removes a greater part

of the harmful bacteria. The horizontal path of flow of bacterial pollution, in sands from a point source such as a well used for artificial recharge, has been found to reach a maximum width of 2 metres. Chemical pollution follows a similar but more extensive path than that of bacterial pollution (Gibson and Singer, 1969).

✓ Entry of pollutants into shallow aquifers occurs by percolation from ground surface, through wells, from surface waters and by saline water intrusion. The extent of pollution in ground-water from a point source decreases as pollutants move away from the source until a harmless or very low concentration level is reached. Because each constituent of a pollution source may have a different attenuation rate, the distance to which pollutants travel will vary with each quality component.

An important aspect of ground-water pollution is the fact that it may persist under ground for years, decades or even centuries. This is in marked contrast to surface water pollution. Reclaiming polluted ground-water is therefore much more difficult, time consuming and expensive than reclaiming polluted surface water. Underground pollution control is achieved primarily by regulating the pollution source and secondarily by physically entrapping and when feasible removing the polluted water from the underground.

2.3.3 Soil Pollution

Soil gets polluted in a number of ways which are grouped together and broadly described as mechanical or gravitational. In the Tamar valley mining district in the west of England 41 per cent of the apparently productive pastures in the study area was contaminated by heavy metals and in many cases this was because of the dispersal of dump material from a landfill. The disposal of metals away from heaps is also aided by moving water. During a survey of gardens in the west of England, Davies (1980) found a flower bed in which few plants survived to maturity. Inspection revealed that the garden wall was built from dump material and subsequent analyses of the garden soil showed 365 ppm Pb, 778 ppm Zn and 684 ppm Cu. Transportation of concentrates or dump material is a possible source of pollution. The use of organic wastes and similar materials to replace traditional manures and composts has caused considerable concern in recent years.

Le Riche (1968) first reported metal contamination of soil resulting from the long term use of sewage sludges. These materials were applied regularly between 1942 and 1961 to light textured land at Woburn, England. Soil samples were taken from two control plots and from two plots which had received a total of 568 tons sludge acre^{-1} (1272 t ha^{-1}). There were clear differences

between the plots in terms of metal content and in the composition of vegetables grown on the soil. Moreover, further analyses six years after the termination of sludge applications revealed that the toxic metals were retained in the soil so that the continuous use of sewage sludges could present a long term danger. Further investigations indicated that copper, tin and zinc were found in sludges in quantities approximately forty times that found in normal soil and zinc was present in highly soluble form. Other metals were also enriched in sewage composts. Trace metal contents varied widely according to the town of origin and it was concluded that the use of these materials without ascertaining their composition could be hazardous.

2.3.3.1 Soil pollution due to organic wastes: The main factors determining the heavy metal concentration of soils are usually the composition of the parent material and the pedogenic processes in soil formation. Many studies have shown that parent materials of comparable characteristics can result in soils with different trace metal concentrations.

A major difficulty in predicting potential hazards associated with land disposal of organic solid waste is the inherent variability in the composition of wastes. Nearly every metropolis has industries that dump their wastes into the normal solid waste disposal

channel. The solid waste refuse is, therefore, extremely heterogenous and the manures obtained from such wastes can also be expected to vary widely in their composition.

Urban solid wastes and composts

Purves and Mackenzie (1973 and 1974) reported that the unleached composts may be high in available boron. Boron caused severe toxicity when stredded refuse was incorporated. Boron toxicity was more severe where NH_4^+ , NO_3^- were added to correct N deficiency and it lowered the soil pH. Much of the B was present in the glue used on labels and in corrugated paper board (Cottrell, 1975). Thus potential phytotoxicity exists for B, Zn, Cu and Ni. Not only is refuse heterogenous in total content of an element, but the chemical forms of the elements also vary. Zinc may be present as sulfide, hydroxide, carbonate and chromate or Zn metal or galvanized steel, and it can be in rubber or within colored glass. It can be an insoluble pigment used in paint or on paper as ink (Eaton et al., 1975). Each of the elements can be present in different forms.

Giusquiani et al. (1988) stated that Italian urban waste composts contained total Pb 263.0 ppm and ammonium acetate + EDTA extractable Fe-97, Cu 9.8 and Zn-355 and Mn 7.0 ppm.

Gray and Biddlestone (1980) reported the results of two field experiments-one on an alkaline clay soil and the other on an acid sandy soil, in which heavy dressings of $250 \text{ t ha}^{-1} \text{ yr}^{-1}$ of composted town refuse were applied. As expected, trace element contents of the soils increased but the only harmful effect on the vegetable crops grown was a depression of seed germination and growth of dwarf beans. This was associated with large increases in the water extractable boron contents of the compost treated soils and was thought to be due to boron toxicity as reported by Purves and Mackenzie (1973 and 1974). Analyses of the vegetable crops like dwarf beans, lettuce, potatoes, spinach and beet grown in the experimental plots showed some increase in trace element concentrations where the compost has been applied but they were small in relation to the quantities added to soil.

2.3.3.2 Identification of soils contaminated with heavy metals: Obtaining pedologically similar soils for use as control in studies on soil pollution with heavy metals often poses a problem. As stressed by Mitchell (1964), parent material is the primary factor determining the composition of trace elements in soils. It is possible to recognise a soil contamination problem with heavy metals only after analysing the profile of heavy metal content in soils. While using soil data it is

important to use carefully chosen control which is pedologically related to the soil which is suspected to be contaminated. It is important that unpolluted soils may cause injury to crops and livestock whereas soil contamination is not necessarily synonymous with biological injury. Indeed, pollution can sometimes be a good thing in that natural micronutrient deficiencies may thereby be rectified.

2.3.3.3 Background levels of heavy metals in soils: In recent years, a great deal of concern has been expressed over problems of soil pollution with heavy metals due to rapid urbanization and industrialization (Leeper, 1978). The heavy metals are part of nutritional chain from soil to plants to animal and human beings. The background levels of heavy metals in soils are determined by the levels that existed in the parent material and by their redistribution in the profile due to pedogenesis during the process of soil formation. Determination of heavy metal status would provide valuable information for the assessment of soil pollution. Comprehensive data on background levels of heavy metals in Indian soils are not available and whatever is reported in literature even when compiled will be only fragmentary. Sources in the literature list typical analyses of rocks, soils and vegetation collected from uncontaminated areas (Bowen, 1966; Aubert and Pinta, 1977). These are useful for comparison with data from areas suspected to be contami-

nated. Tables 3, 4 and 5 list data for rocks, soils and vegetation, respectively.

Table 3: Range and mean concentrations (ppm) of some metals in rocks (Cannon *et al.*, 1978)

Element	Basaltic Igneous	Granitic Igneous
Cd	0.006 - 0.6 (0.2) ^a	0.003 (0.15)
Cr	40 - 600 (220)	2 - 90 (20)
Co	24 - 90 (50)	1 - 15 (5)
Cu	30 - 160 (90)	4 - 30 (15)
Pb	2 - 18 (6)	6 - 30 (18)
Ni	45 - 410 (140)	2 - 20 (8)
Zn	48 - 240 (110)	5 - 140 (40)

a - Numbers in parenthesis are mean concentrations.

Table 4: Elemental composition of typical uncontaminated soils (Bowen, 1966 and Etherington, 1982)

Metal	Mean concentration ppm (dw)	Range ppm (dw)	Range above which causes pollution (ppm)
Cd	0.06	0.01 - 0.7	0.5+
Co	8	1 - 40	--
Cr	100	5 - 3000	5+
Cu	20	2 - 100	5 - 30
Fe	38000	7000 - 550000	--
Mn	850	100 - 4000	--
Ni	40	10 - 1000	2 - 20
Pb	10	2 - 200	2 - 10
Zn	50	10 - 300	1 - 90

Table 5 Elemental composition of uncontaminated plant tissues (ppm) (Bowen, 1966; Allaway, 1968 and Etherington, 1982)

Metal	Range in agricultural crop plants	Range above which causes pollution problems
Cd	0.2 - 0.8	0.1 - 0.5
Co	0.05 - 0.5	--
Cr	0.2 - 1.0	0.1 - 0.5
Cu	4 - 15	4 - 5
Mn	15 - 100	--
Ni	1	1 - 5
Pb	0.1 - 10	1 - 15
Zn	15 - 200	10 - 50

The trace elements are generally present in rocks and concentrations vary considerably depending on the type of rock. Therefore, consideration must always be given to the nature of the soil parent material when interpreting analytical data to identify polluted situations.

Kuhad et al. (1989) determined heavy metals in agricultural soils of three physiographic zones of Haryana. The values were found to be low and represent levels naturally occurring in uncontaminated soils. The levels of most of the metals were either depleted or remained unaffected in the A horizons associated with C

horizons with the exception of Cu and Mn. The contents of total Cd, Pb, Ni, Co, Zn, Cu, Mn and Fe in the surface horizons of the soils ranged from 0.50 to 1.25, 10.0 to 32.5, 20.0 to 40.0, 11.4 to 29.0, 15.0 to 53.4, 25.0 to 100.0, 100.0 to 322.0 and 17750.0 to 40625.0 ppm, respectively.

The heavy metal levels in the surface horizons for normal soils is also reported in literature by Swaine (1955). In general, there was no regular trend in the content of metals in different horizons of pedons (Kuhad et al., 1989). They attributed the depletion of the metals in AP (surface) horizons to be due to their possible leaching.

Misra et al. (1990) reported DTPA-extractable concentrations of heavy metals viz. Zn, Cu, Cd, Ni, Pb and Cr in vertisols of Hyderabad region as 2.2, 2.6, Nil, 0.6, 0.8 and nil ppm, respectively

Background values usually refer to a framework of time rather than concentration. Background levels commonly provide a reference point for comparison. The so called background levels established in an already contaminated area may provide a misleading or false reference point, resulting in the under-estimation of the health risk of new industrial or agricultural enterprises or practices. We need to understand better

regional and local variations in natural soil background values.

2.3.3.4 Ecological consequences of heavy metal pollution of soils: The ecological consequences of heavy metal pollution of soils relate largely to heavy metal mobility and solubility. These chemically related factors determine transmission through the soil to the water table, availability to soil microbes, agricultural crops and animals and ultimately to the human population. Leaching of heavy metals through soils to groundwater, even in soils treated with sewage sludge, is reported, however, not to occur to any appreciable extent (Leeper, 1982; Emmerich et al., 1982).

Effect on soil crop animal system: At moderate levels of heavy metal concentrations, above the deficiency range, most natural soils act as a repository or sink for metals without any obvious effects on soil biological behaviour. The important question is the response of plants and animals to increasing concentrations of metals that result from natural variability or from pollution. The extent of transfer of metals from soil to plant depends on the kind of plant, the particular metal involved and the soil chemical environment.

Uptake of metals by plants reflects increasing levels of metals in soils, especially the mobile ones.

Above certain critical concentrations of heavy metals in plants, yield and or crop quality and animal or human health may be affected. Concentrations of toxic metals require careful monitoring, because potentially dangerous levels may be reached in the plant food diet of animals or humans without any evidence of deleterious effects on the plants. This is especially so for Cd and Pb for which plant toxicity occurs above the concentrations considered desirable for human intake. The reverse is true for other heavy metals, for example Zn, Cu and Ni for which the concentrations causing yield depression of plants are below those of risk to humans and animals, if the plants are ingested as food. This provides a built-in safety mechanism for such elements.

Heavy metal pollutants rarely occur alone. The associated elements, frequently other heavy metals and possibly major nutrients also can affect the biological effectiveness of the metal in question by additive, synergistic, or antagonistic effects. It is clear (Page et al., 1981) that at least as far as Cd is concerned, the interactive effects of different metals cannot easily be generalized. Interactions of Cd with Zn for example, can be positive, negative or non-existent, depending on the relative concentration levels, in soil and crop.

The impact of heavy metal pollution on health also depends on the nature of the association of heavy metals with plants. The heavy metals associated with plants are not necessarily absorbed by the root system and translocated within the plant. In some regions, appreciable amounts of some heavy metals can adhere directly to leaf surfaces after deposition from the atmosphere. Contamination of pasture plants by the spreading of agricultural waste slurries and by adhering soil splash and soil dust also contributes to the metal intake by farm animals. Surface contamination of food plants and the direct ingestion of soil together with forage plants can complicate predictions on health hazard to both animals and humans (Healy, 1973).

2.3.3.5 Impact of heavy metal pollution of soils

a) **Degree of soil pollution:** Assessment of the degree of soil pollution calls for analysis of the total concentration and comparison with an appropriate reference soil, analyzed in the same way which represents the normal background situation.

Analysis of total heavy metals provides information on the metal load of a polluted soil. For more useful data on the degree of soil pollution, the total concentration of any heavy metal may be divided into different chemical components. Procedures that only

partially remove labile metals from soils may usefully predict uptake by crop plants (Davies, 1980b).

b) Uptake of metals by plants by means of soil analysis: Soil analysis has been widely used to know whether the micronutrient metal status of a plant lies in the deficient, normal or toxic ranges. This approach has been widely used as a basis for amending the soil appropriately. The same principle is applied to uptake of toxic heavy metals. It is generally accepted that the prediction of trace metal uptake by plants is best achieved by the analysis of soil solution or any comparable parameter (Kabata-Pendias and Pendias, 1984).

The DTPA soil test generally reflects the labile metal load of a soil. Increases in DTPA-extractable metals, however, do not mean increases in plant available metal or increased plant uptake (O'Connor, 1988). If initial soil nutrient concentrations are already sufficient, further increases in nutrient concentration may increase plant metal concentrations imperceptibly leading to what is familiarly called as the Plateau effect (Corey et al., 1987).

Barbarick and Workman (1987) point out that when sludge treatments do not significantly increase plant uptake relative to control treatments, non-significant correlations (DTPA metals vs. plant concentrations) result. Thus, low metal sludges applied at low

(agronomic) rates are unlikely to produce significant sludge treatment effects although DTPA-extractable metal concentrations may increase. Similarly, even high metal sludge (or high metal loadings) applied on certain calcareous soils often yield non-significant sludge treatment effects, although DTPA extractable metals dramatically increase (McCaslin and O'Connor, 1982).

c) **Prediction by plant analysis:** Plant analysis gives an indication of the available heavy metals in soils as well as defining the plants own metal load, which is important when the plant is ingested as food or animal feed. For many researchers, the analysis of plant tissue is the preferable approach when assessing the soil status of nutrient and toxic elements. According to this view, the plant is the only acceptable judge of the soil's ability to transmit the elements under consideration. However, metal uptake may vary appreciably between genotypes and among different plant parts. Metal status is also influenced by plant maturity, environmental factors like light, temperature, soil moisture, rooting depth and interactions with other metal pollutants and nutrients (Davies, 1980b)

2.3.3.6 Effect of urban solid wastes on soil profile characteristics: Land application of municipal and urban solid wastes could be one of the most economical and attractive propositions to solve two problems :

Waste disposal and the need to increase the organic matter content of soils (FAO, 1975 Chen and Avnimelech, 1986). However, evaluation of the effects of municipal and urban composts on soil fertility is a necessary preliminary task before establishing the real advantages of their use in agriculture (Bauduin et al., 1987).

Soil constitutes a natural resource for recycling or disposing wastes. Allaway (1968) noted that the soil route is the predominant path way for transfer of many elements to plants, including heavy metals.

The Environmental Protection Agency of the United States of America (EPA) stated that land application is indeed a viable alternative to municipal waste management system. In fact EPA outlines that if land treatment can be demonstrated to be the most cost-effective alternative consistent with the environmental assessment and other aspects by satisfying applicable tests, it should be used in lieu of other systems of waste treatment.

At present, a good proportion of the city garbage is dumped in low lying areas and may become an important source of ground-water pollution. The movement of water first through garbage dumps and then through soil also results in soil pollution. The bio-

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degradation, leaching and volatilization of constituents in city garbage results in serious land, air and water pollution (Liptak, 1974).

Excellent reviews are available on soil modifications to minimise movement of pollutants from solid waste operations (Fuller, 1980) and on the effect of application of town refuse compost on the soil-plant system (Gallardo and Nógales, 1987).

Effects of sanitary landfill leachate on some soil chemical properties: Sanitary landfill are used widely to dispose of municipal solid waste. Problems that arise even with apparently properly constructed sanitary landfill include, leachate generation when the surface is permeable, methane production, surface runoff and erosion when the surface is impermeable.

Since many landfills are located in natural drainage basins, leachate generated may surface at some point below the landfill or may even enter ground-water aquifers. When this happens, serious pollution problems develop that are difficult to manage by conventional methods (Ham and Boyle, 1971). These include discoloration of the water, Fe precipitates that coat land surfaces and vegetation, diminished dissolved oxygen, nutrient enrichment and toxic metal contamination of streams and ground water.

A survey of literature on these aspects reveals that the information generated so far though not meagre is fragmentary. The contribution of Winant et al. (1981) deserves a detailed review because of its comprehensive coverage of the aspects of pollution.

They studied the effect of sanitary landfill leachate on soil chemical properties to a depth of 60 cm and reported that the leachate supplied more Ca and Mg than did lime. The Mg : Ca ratio in the leachate was much higher than that of native limestone and soils of the area. Leachate Zn and Pb loading greatly exceeded those from soils amended with lime and rock phosphate.

Chain and De Wallace (1976) reported higher Ca, Mg and Na concentrations and lower K, Mn and Zn concentrations in leachate. The levels of Cu, Pb and Cd in landfill leachates were similar in both the studies of Chain and De Wallace (1976) and Winant et al. (1981). The latter study revealed further that application of leachate as spray to soils significantly changed the extractable soil Ca, Mg, K, Mn, Fe and Zn levels as compared with pre-spray values.

Exchangeable calcium: Appreciable amounts (26% of amount applied) of Ca moved into the soil profile to the 30 cm depth. This only accounts for the extractable Ca. The CEC increased from 21 to 30 meq 100^{-1} g at the

0 to 5 cm soil depth. This may be due to organic chelation (Hodgson et al., 1965).

Exchangeable magnesium: Leachate increased the extractable Mg content upto 30 cm depth, however, more than one half of the total extractable Mg was retained in the depth less than 5 cm.

Farquhar (1977) showed that Ca and Mg were dissolved by addition of leachate to soils with initial pH values of 7.1 - 7.4.

Exchangeable potassium: The leachate applications more than doubled the amount of extractable K in soils. The increase in extractable K in soil accounts for 76 per cent of the applied leachate. Adsorption processes were considered to be the likely cause of K retention (Griffin and Shimp, 1976; and Farquhar, 1977).

Extractable Mn, Fe and Zn: Extractable Mn was significantly higher at soil depths of 30 cm in all the leachate treated plots. The largest amounts of extractable Fe were found in the first 5 cm of soil. At the 0-5 cm depth, extractable Zn increased significantly. Farquhar (1977), Griffin and Shimp (1976) and Ham (1975) observed decrease in Zn content with depth. At the 5 to 30 cm depth, the values for extractable Zn ranged from 0.3 to 1.3 ppm.

Total N: Leachate application increased total N in the soil upto a 15 cm depth. Most of the N was recovered in the first 5 cm of the soil (Winant et al., 1981).

Extractable P: Leachate contributed only 42 kg ha⁻¹ of P. Municipal solid wastes contain as much as 0.26 per cent P on dry weight basis (Volk, 1976). However, leachates have low P concentrations (Chian and Dewallace, 1976) and analysis of leachate for P is subject to major interferences (Chian and Dewallace, 1975). Griffin and Shimp (1976) found low phosphate concentrations in Dupage county (USA) sanitary landfill leachates.

Exchangeable sodium: Exchangeable Na levels increased by four folds over control values of i.e., 25 ppm to 108 ppm at surface and 14 ppm to 100 ppm at 30 cm depth of soil.

Soil pH: Leachate application increased soil pH significantly to a 30 cm depth i.e. pH 4.7 to 5.8 at the 0-5 cm and from 4.5 to 5.7 at 15 to 30 cm depth (Winant et al., 1981).

Most elements were attenuated to some extent by movement through the soil.

Mesmeci et al. (1985) studied the leachate quality, soil attenuation and movement characteristics

of some metals (Fe, Pb, Al, Cd and Cu) in samples collected by drilling at increasing depth in two landfills (A and B) in Italy. The results showed an attenuation process in the soil below wastes. In the refuse layers, the metal concentrations in landfill A are lower than in landfill B which was associated with refuse age. Further, they concluded that the reduction in metal concentrations in the soil layers and the differential release of metals from the soil is correlated to different soil characteristics.

2.3.3.7 Profile distribution of micronutrients in agricultural soils in India: A knowledge of nutrient distribution vertically down the soil profile is important to assess the contribution of sub-surface soil layers to crop nutrition and the potential capacity of the soil to supply nutrients during crop growth. Besides, it helps to understand the effect of different management practices under a given cropping system on the downward movement as well as recycling of nutrients to the surface layers.

Results of some studies conducted on Zn, Cu, Mn and Fe in India on this aspect are reviewed by Takkar et al. (1989) and the same are summarised here.

Zinc: Zinc showed an irregular pattern of distribution in Hissar (Haryana) soils. The DTPA'

extractable zinc followed closely the organic carbon and the clay content (Takkar et al., 1989). Some profiles exhibiting consistently higher DTPA extractable Zn had low organic carbon and clay contents in profiles.

Katyial (1982) studied the profile distribution of DTPA-Zn in 57 bench mark soils of India. Zinc content markedly declined after A horizon and remained almost constant thereafter, along the depth of the profiles of Haldi and Channasandra series. In profiles from other series, however, its distribution showed an erratic pattern.

A regular downward decrease in available zinc was noticed by several authors in the alkali soils under reclamation in Punjab, which seems to be associated with organic carbon content which also decreased with depth (Takkar et al., 1989).

In Mahaboobnagar district of Andhra Pradesh, India the distribution of available zinc in seven profiles belonging to different series showed that DTPA-Zn failed to show any definite pattern of distribution with depth. Nevertheless, its significant correlation with pH ($r = 0.45$ to 0.53) and organic carbon ($r = 0.43$ to 0.48) indicated that its distribution was regulated by these two soil properties (Takkar et al., 1989).

Jalali et al. (1989) reported that the total Zn decreased with depth of soils. Total and available micronutrients were influenced by soil properties viz., pH, organic carbon, clay and CaCO_3 contents.

Singh et al. (1988) reported that the surface horizons of all the profiles had higher content of available Zn which in most cases decreased with depth. Sakal et al. (1988) stated that available Zn was significantly and negatively correlated with pH and positively with organic carbon. Available Zn showed a significant negative correlation with soil salinity and positive correlation with available P_2O_5 .

Copper: Like Zn, the content of DTPA-Cu was also more in A horizon as compared to lower horizons where it showed a marked decline. In the alkaline soils of Punjab the DTPA-Cu content had a tendency to decline with soil depth, in alkali soils it showed an accumulation in the 15-30 cm layer and then a regular decrease upto 60-90 cm depth. The surface (0-15cm) layer invariably had higher content of available Cu compared to the 30-60 and 60-90 cm layers. In Andhra Pradesh DTPA-Cu was uniformly distributed in Oblallapally series, whereas in Palem and Peddadevarapally it decreased at 56-65 cm depth. Jalali et al. (1989) also reported that the total Cu decreased with depth in soils.

Sakal et al. (1988) stated that available Cu was significantly and negatively correlated with pH and positively with organic carbon. Available Cu showed a significant negative correlation with soil salinity and positive correlation with available P_2O_5 .

Iron: The DTPA-Fe content exhibited a sharp decline in soil profile upto A or B_{21} horizons and thereafter, it showed a regular decrease except in one (Kheri) profile where its content remained constant. In different soil series of Mahaboobnagar in Andhra Pradesh, irrespective of the type of soil, the DTPA-Fe content in almost all the profiles showed a regular decrease from surface downwards. In alkali soils under reclamation the content of DTPA-Fe showed a regular decline with depth. The distribution of available iron along the soil profile seemed to be regulated by the soil reaction in sandy loam soils and by the manganese compounds ($r = -0.75$) extractable by DTPA as evident from its significant correlation (Takkar et al., 1989).

Jalali et al. (1989) reported that the total Fe decreased with depth in soils.

Singh et al. (1988) studied the profile distribution of available micronutrients and found that the surface horizons of all the profiles had higher content of available Fe than soils at lower depth which may be partly attributed to the higher organic carbon and less

CaCO_3 content in the surface horizons than sub-surface horizons.

Sakal et al. (1988) stated that available Fe was significantly and negatively correlated with pH and positively with organic carbon.

Manganese: Like Fe, DTPA-Mn did not follow any pattern of distribution along the profiles of different soils. The content of DTPA-Mn decreased upto B_2 Ca and B_{23t} horizons and increased consistently thereafter. In different soil series of Andhra Pradesh, pH was found to regulate Mn content along the soil profile. A strong relationship ($r = -0.92$) between pH and DTPA-Mn particularly in red sandy loam soil revealed this fact. In alkali soils under reclamation in Punjab (India) the DTPA-Mn showed an accumulation in 15-30 cm layer beyond which it experienced a consistent decrease with depth. However, in some soils of Uttar Pradesh (India) the DTPA-Mn exhibited a regular decrease from surface downwards.

Prasad and Sahi (1989) studied the distribution of manganese in soil profiles. The DTPA-Mn ranged between 3.5 to 78.4 ppm in the profile samples which decreased with depth. Total manganese content of soil varied from 120 to 1110 ppm. The higher content of total manganese in soil profiles was considered to be

due to presence of manganese bearing minerals in the parent material. In general, the content of total manganese increased with depth. Clay content and organic carbon positively influenced the status of total manganese.

Jalali et al. (1989), however, reported that the total Mn decreased with depth in some Indian soils.

Singh et al. (1988) studied the profile distribution of available micronutrients and found that the surface horizons of all the profiles had higher content of available Mn which in most cases decreased with depth.

Sakal et al. (1988) stated that available Mn was significantly and negatively correlated with pH and positively with organic carbon.

2.3.3.8 Distribution of pollutant heavy metals in soils: Mitchell (1964) has reviewed the distribution of trace elements in soil profiles and from his experience in Scotland suggested that copper, lead and zinc tended to be enriched in surface, organic matter rich horizons. In case of lead, most investigators agree that it accumulates in the top soil. A marked and fairly regular increase in concentration from the lowest horizon to the surface in English brown earths and grey soils was found. Swine and Mitchel (1960) found such

lead accumualtion in this way even in remote rural areas and believed it to be caused by an increase in lead content of vegetation in the autumn prior to their fall to the soil surface.

The nitric acid soluble lead content of agricultural soils in England was related to proximity to industrial and densly populated centres and that lead originating from contamination was immobilized in the topsoil (Davis, 1980 b). Rolfe and Jennett (1975) compared two profiles from rural and urban areas. Lead was strongly concentrated in the 0-100 mm horizon of both profiles but in the urban profile, there was evidence that some lead has been leached to the 400-800 mm layer. Surface enrichment of lead has also been noted from automobile exhausts. Some trace elements are concentrated in the top soil and many of them are redistributed in the profile whether they initially came into the solum through the weathering of the adjacent parent material or were added by some contamination process. The question, therefore, arises whether leaching of the profile is likely to lead to substantial diminution of the content of contaminants over short or medium periods. Purves (1972) stated that toxic metal levels were not substantially reduced in soil columns after leaching with the equivalent of 40 mm rainfall.

The lead was immobile in soils and the presence of lime increased the retention of trace elements. The retention properties of divalent cations were best related to clay content and surface area whereas the hydrous oxides seemed to be the dominant controlling factor for anions.

The order of contribution of the total trace element content of the mineral fractions was clay, silt, sand but much of the copper and lead was found in the organic matter and the oxalate-extractable iron oxides. Thus, the importance of the contribution of the finer soil grades to the total trace element content is well established even for comparatively young soils (Davies, 1980 b).

The clay fraction is enriched in metals compared with the other grades and is the largest reserve of heavy metals. Only for zinc does the silt fraction have any special importance. One can conclude that the distribution of metals in the mechanical fractions of a contaminated soil after a long period of weathering is similar to that of uncontaminated soils, even when their respective source of minerals are considerably different (Davies, 1980 b).

Localization of trace metals in soil: There are many reports of decreasing trace metal concentrations with increasing depth below soil surface (Smith,

1976 and Ragaini et al., 1977). It has been suggested (Tyler, 1972) that this pattern of trace metal distribution is related to the rather similar pattern of organic matter distribution in soil profiles. Chelation is of importance for those metals which tend to form stable complexes, such as those of copper and lead (Begovich and Jackson, 1975). This is confirmed by the enhancement of trace metal mobility in soil by the presence of soluble organic compounds (Bolter and Butz, 1975 and Witkamp and Ausmus, 1976). This effect is particularly marked for those trace metals which readily form complexes. Just as mobile (i.e., dissolved) organic compounds increase the soil mobility of readily complexed trace metals, so is the fixed (i.e., non-dissolved) organic compounds, in litter and humus, provide reservoirs of complexing agents. Consequently, soil containing very high amounts of organic matter show least leaching from litter for the most readily complexed trace metals such as lead and copper and most leaching for less readily complexed metals such as zinc and cadmium (Tyler, 1978).

Metal mobility is also related to sorption by clays and hydrous metal oxides (Page, 1974 and Ellis and Knezek, 1982). Trace metals may also be rendered immobile by the formation of sulphides which is redox dependent, carbonates or phosphates, all of which depend

on a number of facets of soil chemistry and pH. Clearly the location, mobility and chemical form of soil trace metals determine their availability to plants for recycling. Furthermore, the more mobile a trace metal, the more readily it may be lost from the eco-system to ground water or stream flow as a result of vertical or lateral water movement.

2.3.3.9 Effect of urban solid wastes application on soil properties: The urban and municipal solid wastes either fresh or composted, are being used increasingly in areas adjoining the municipal or urban surroundings for agricultural purpose. This has prompted many workers to study the impact of application of such wastes on soil properties.

Hortenstine and Rothwell (1969) reported that compost applications increased P, K, Ca, Mg and soluble salts in the soil. Water holding capacity and CEC were also increased.

Srivastava et al. (1971) evaluated the urban compost and reported that the C/N ratio of 15-20 was satisfactory for soil application.

Mays et al. (1973) reported that the municipal compost improved soil physical and chemical properties but caused zinc toxicity to plants.

In contrast, Terman et al. (1973) reported that the compost made from garbage contained N, P, K and Zn and had a considerable liming effect which prevented zinc toxicity.

Webber (1978) studied the effect of incorporation of non-segregated, non-composted urban solid waste on soil properties. The results revealed that the soil carbon, nitrogen and water stable aggregation increased and bulk density (BD) decreased with increments of solid waste added. In greenhouse studies Nogales et al. (1984) reported that urban compost increased total soil porosity.

Addition of sewage sludge and compost on soil increased zinc in upper soil layers (Furrer, 1979).

Sotomayor (1979) concluded that addition of refuse compost increased P, K and organic matter contents of soils.

Spittler and Feder (1979) observed that soil samples from urban gardens contained an average Pb level of 800 ppm, the highest Pb concentration being in the finest soil fractions.

Subbaiah and Ramulu (1979) reported that application of sewage wastes decreased soil pH and increased soil salinity, CEC, organic carbon, available P and exchangeable bases.

Otsuka and Adachi (1980) found that application of town refuse compost to soil increased the pH, humus and exchangeable Ca. of the A_p horizon.

Fuller (1980) discussed the relevance of several soil properties in relation to their capacity to retain pollutants from solid wastes and their leachates.

Haon (1981) reported results of municipal waste compost research conducted over more than 50 years at the Institute for Soil Fertility at Haren, Netherlands. He concluded that micro-element contents and Ca and S levels in the city refuse compost are high, and N, P and K contents and their availability are low whereas the organic matter content was 30 per cent on dry matter basis. Biennial applications of upto 40 t ha⁻¹ of compost between 1948 and 1975 resulted in large increase in micro element concentrations in crops and more so in soils.

Kowaed et al. (1982) reported that the applications of 40, 80 or 120 t ha⁻¹ refuse compost over a two year period increased the soil pH from 5.1 to 5.9, 6.2 and 6.5 respectively. Carbon contents of the soil increased from 1.25 to 1.59 per cent. Phosphorus and K contents increased with increasing rate of application. Cereal yields were not more than with chemical fertilization.

Lairon et al. (1982) indicated the usefulness of town refuse compost under tropical conditions. The balanced ratio of minor elements and the low content of heavy metals make this material a useful resource augmenting organic matter content of tropical soils.

Watanabe and Furihara (1982) discussed the characteristics of municipal refuse composts in relation to their decomposition in soil and their effect on nitrogen availability to plants and soil and plant heavy metal contents. The heavy metal content of some solid wastes produced in residential areas, a market, a cafeteria and the composts in Ibadan, Nigeria were investigated by Sridhar and Bammeke (1986).

Gallard O-Cara and Nogoles (1987) reviewed the effects of refuse compost on soil physical, chemical and biological properties and on nutrient availability.

Refuse compost applied at 156.0 or 311.0 tonnes dry matter per hectare to 35 cm depth to poor sandy soil increased soil pH, K_2O , P_2O_5 and N and of Ni, Cr, Cd and Pb (Schossing, 1983).

According to Schliemann and Kotze (1984) mature (stabilized) municipal compost was not phytotoxic at normal agricultural application rates and from the plant

nutritional point of view would be acceptable as a substitute for FYM and farm compost.

Pelletin et al. (1986) reported that application of town refuse compost from various sources or town refuse compost plus sewage sludge or cattle manure in field did not cause any great differences in yield of crops under field conditions. No accumulation of metallic elements in the soil was found due to the use of composts. It was concluded that there was no indication that fresh composts should not be used.

Giusquiani et al. (1988) studied the influence of urban waste compost on soil fertility under laboratory conditions. No change of pH and CEC values were observed, whereas the compost addition increased the solubility of phosphorus. Exchangeable potassium increased three fold and Zn remarkably, whereas available Fe and Cu concentrations were not affected. Available Mn increased. It was concluded that only Zn increased remarkably and could cause problems of phytotoxicity.

Haertling (1989) reported that all trace metal concentrations increased considerably below the dump at municipal waste disposal site at Pangui Tung, China.

Hernando et al. (1989) found that application of municipal refuse compost improved soil physical structure and alkali soluble substances.

Murillo et al. (1989) reported that successive application of city waste compost on rye grass and tomato increased soil N, oxidizable organic matter, P and CEC in the top 0-10 cm soil and at a depth of 12-22 cm following applications of 150 and 400 t compost per ha. However, a parallel significant increase of heavy metals (total and DTPA extractable fractions) was also observed at the two depths. Sodium content occasionally reached levels close to three per cent which could cause problems and they suggested that compost quality control would be an important factor.

Municipal organic wastes offer many benefits for application to soils, including increased soil fertility, increased water retention in the soil decreased soil erosion and decreased fertilizer requirements (Glaub and Golueke, 1989).

King et al. (1974) studied the feasibility of using land for both waste disposal and crop production by applying pulverized municipal refuse. Refuse was applied at 188.0 and 376.0 t ha⁻¹. Soil pH in the 0 to 15 cm zone was not affected by refuse application but a slight decrease in pH occurred in the 15 to 30 cm layer wherever refuse had been applied. Also there was an increase in conductivity due to application of refuse. All conductivities were below the 500 $\mu\text{S m}^{-1}$ level

which is the upper limit for proper seed germination (Brooks, 1969).

Petruzzelli et al. (1989) studied four year compost treated soil for heavy metal extractability. Copper concentration increased from 16.0 to 25.4; Zn 21.1 to 37.4; Pb 9.2 to 16.1; 1.3 to 1.9; Ni 3.8 to 6.7 ppm in DTPA extractable form. Soil pH increased by 0.50 pH units. The electrical conductivity increased from 0.07 S m^{-1} to 0.11 S m^{-1} following the treatment with a low rate of compost upto 0.20 S m^{-1} for the highest addition ($30 \text{ t ha}^{-1} \text{ yr}^{-1}$). Highest rate of compost increased soil organic carbon from 0.09 to 0.17 per cent.

2.3.3.10 Effect of farm yard manure and other organic waste applications on soil properties: The objective of many manurial experiments during the last 20 years has been to determine the maximum application rate for land disposal of waste. To reduce handling costs and to avoid storage problems over $700 \text{ metric tonnes ha}^{-1}$ have been tested experimentally (Manges et al., 1971). Toxic effects on yields or inferior crop quality have to be considered in a management programme. Environmental pollution hazards to streams or ground waters must be eliminated or reduced to acceptable levels.

Excessively high manure rates for disposal caused problems. These problems centered around salt

injury and NH_3 toxicity to crops, high NO_3 in foliage adverse K: (Ca + Mg) ratios in forage and trace element accumulations to possible toxic levels (Azevedo and Stout, 1974).

In contrast, disposal rates of manure over 700 t ha^{-1} have been tested (Manges et al., 1971), but crop yields were depressed when rates exceeded 204 t ha^{-1} . Grain sorghum (Sorghum bicolor Moench) yields under irrigation were reduced when the rate exceeded 134.0 t ha^{-1} , but 22.0 t ha^{-1} was adequate for maximum yield (Mathers and Stewart, 1971).

2.3.3.11 Salt accumulation: Reduced crop yields can result when waste materials add excessive amounts of soluble salts to soils. This problem generally arises from high rates of application of organic wastes or secondary effluent, especially in arid or semiarid regions. Reduced yields due to salinity effects have been observed in several studies with animal wastes (Wallingford et al., 1974; Mathers et al., 1972).

Excessive salt accumulation also can decrease seed germination and deteriorate soil structure due to high concentrations of Na. The presence of soluble salts and/or organic materials resulted in decreased germination and emergence for several crops planted in soils treated with sewage sludge, animal waste or

compost (Hortenstine and Rothwell, 1969; Sabey and Hart, 1975; Cunningham et al., 1975). For secondary effluents and waste waters from processing plants, the SAR (sodium adsorption ratio) and electrical conductivity are useful parameters to evaluate potential problems arising from salt accumulation in soils.

2.3.3.12 Seed germination: Nogales et al. (1984) in an experiment reported that the saturation extracts of mixtures of soil and urban refuse compost depressed the germination of barley, perennial rye grasses, bean (Phaseolus vulgaris) and tomato. Tomato was most sensitive to compost addition, showing 10 per cent of germination with 10 per cent (w/w) compost addition to soil. Barley was the least sensitive, showing 50 per cent germination with 100.0 per cent compost addition to soil (w/w).

Aqueous extracts of the composts inhibited germination and root elongation of B. pharachinensis. The inhibition was greater at higher extract concentrations and declined with increasing compost age. This was related to high concentrations of ammonia and ethylene oxide in the composts (Wong, 1985).

Hortenstine and Rothwell (1969) observed in laboratory experiments that turnip and radish seed germination in compost extract was reduced and similar

reductions were observed in pearl millet and Oat seeds germination.

2.3.3.13 Leaching of soluble salts: The leaching of soluble salts from organic wastes is influenced by particle size. Soluble salts leach more rapidly from wastes which have a small particle size. Amoozegar-Fard et al. (1975) found that reducing the size of manure aggregates from 4.8 to 2.6 cm. increased conductivity of the leachate from 10.9 to 20.6 mmhos cm^{-1} during the first leaching period, but it decreased from 3.8 to 2.7 during the fifth leaching period. Also, hazardous salts (K and Na) in the manure were highly soluble and were readily leached. However, divalent cations, Ca and Mg, the nutrient materials (N and P) and trace elements were less soluble and migrated more slowly.

Part of the salt in organic wastes is reported to be not soluble initially but is released during decomposition of the waste.

2.3.3.14 On land disposal of fresh USW as manure : Considering the plant nutrients and the carbon contained in domestic organic wastes and sewage sludges, it seems feasible that these wastes can be incorporated directly into soils. The literature contains at least two reports in which non-composted domestic organic solid

waste was mixed with soils under field conditions (Volk and Ullery, 1972; Webber and King, 1974).

In the Boardman, Oregon Project upto 900 t ha⁻¹ of shredded solid waste plus liquid sewage sludge were added to sandy soils (Volk and Ullery, 1972). Fescue (Festuca eliator L.) and alfalfa forage were harvested three times during the summer. The first year yield was slightly reduced with a waste application of 224 t ha⁻¹ but the yield was equivalent or higher than that from the check plots at the second and third cuttings. It was suggested that waste application to sandy soils should not exceed 450 t ha⁻¹.

In a study conducted at Guelph, Canada shredded solid waste (with C/N ratio 65) was spread on the soil surface and ploughed (Webber and King, 1974).

In principle soil incorporation of high carbon wastes with high nitrogen waste (sludges and manures) appears to be attractive proposition but requires a careful evaluation of the possible effects on land, water and plants. There is a vast potential to recycle the nutrients contained in solid wastes provided care is exercised to closely monitor the hazards like accumulation of salts, toxic heavy metals and biological pollutants.

2.4 EFFECT OF URBAN SOLID WASTES ON YIELD AND UPTAKE OF MICRONUTRIENTS AND HEAVY METALS BY PLANTS

In densely populated areas, there is considerable pressure to dispose off the waste products generated in human habitation such as sewage sludge and municipal compost by applying them to agricultural land. Attention has been drawn to the possibility of metal contamination of the soil resulting from application of sewage sludge by Le Riche (1968) and Berrow and Webber (1972). Information on the trace element content of the soil on application of municipal compost, although its composition (Purves, 1972) suggests that this material is a likely source of trace element contamination is fragmentary. Analysis of samples of municipal compost by Purves and Mackenzie (1973) indicated that municipal compost can contain upto 100 times as much soluble boron and copper and 300 times as much Zn and Pb as uncontaminated countryside soils in Scotland. The addition of even moderate amounts of municipal compost to soils can, therefore, be expected to have a pronounced effect on their trace element and heavy metal contents. Since contamination of the soil with certain elements will lead to increased uptake via the plant route, with the possibility of ill-effects either directly on the plants or on animals consuming them, it is important that the

consequence of the agricultural use of this material should be studied.

2.4.1 Effect on yield

Hortenstine and Rothwell (1969) evaluated the municipal refuse as a plant nutrient source and soil amendment in glasshouse experiment and concluded that turnip (Brassica rapa L.) and pearl millet (Pennisetum typhoidenum L.) responded well, in forage yield and plant uptake of N, P and K, to composted town refuse applications above 32 t ha⁻¹. In Oats (Avena sativa L.) foliage yields and N, P, K uptake were greatly increased by 512 t ha⁻¹ compost. For radish (Raphanus sativus L.), best results were obtained with 128 and 572 t ha⁻¹, but 572 t ha⁻¹ also produced some phytotoxic effects.

Vlamis and Williams (1971) reported that application of garbage compost increased yields of tomato, barley and lettuce. On soils of low fertility, garbage compost could be used at rates upto 60 t acre⁻¹.

Mans et al. (1973) obtained significant increase in maize yield to annual applications of 112 t compost ha⁻¹ to maize under field conditions.

Utilization of raw municipal garbage for cultivation of fodder and other commercial crops has been reported by Forti et al. (1977). They proposed the use of raw garbage as a supplement to arid land as a

possible solution to its disposal problem. About 15 t ha⁻¹ raw garbage were spread in furrows and buried. At first harvest, there was a 220 per cent increase in A. comescens and 160 per cent increase in Cassia sturtii.

Sotomayor (1979) evaluated refuse compost as an organic fertilizer for a range of vegetables in a 4 year field trial in Chile. Compost was compared with urea as a nitrogen source, each supplying 200 or 400 kg N ha⁻¹ yr⁻¹ and with superphosphate as a P source. Yields of all plant species were greater with the mineral fertilizer than with the refuse compost.

Clairon et al. (1982) reported that the town refuse compost can be used for improving the humic matter of tropical soils.

In a glasshouse experiment with Brassica parachinensis, Wong (1985) reported that plant growth increased with the application of matured compost at 100 t ha⁻¹. With the commercial compost, the greatest plant growth was produced with 75 t ha⁻¹, which resulted in dry matter yields four times those of the control. Only the fresh compost was reported to be inhibitory to plant growth. Similarly pot culture trials were conducted with increasing rates of town refuse compost on lettuce, spinach and rye grass. Pots containing more than 20 per cent compost decreased yields of spinach and lettuce

while those with highest compost rate gave maximum dry matter for rye grass.

In an eight year study in England where pulverized municipal refuse was applied to soils at rates of 13.2 or 36.5 t ha⁻¹, average yields of most root crops, vegetables and cereals increased (Garner, 1966). However, the refuse applications produced only 72 per cent of the yield increase observed for the same rates of farm manure.

Application of shredded metropolitan waste to irrigated calcareous sandy soils in Eastern Oregon (USA) at rates upto 448.0 t ha⁻¹ (approximately 298 t of dry matter ha⁻¹) did not decrease alfalfa or Fescue (Festuca sp.) yields, (Cottrell, 1975).

Urban waste may be applied to agricultural soils but this practice has not been followed because of health hazards to cattle from ingestion of foreign objects, equipment unavailability, high hauling costs, potential pathogenic problems and possible boron toxicity to sensitive plants.

Application of municipal compost at 0, 23, 46, 82, 246 and 327 t ha⁻¹ for two years⁻¹ containing upto 20 per cent sewage sludge to forage sorghum, common Bermuda grass and corn increased sorghum yields over a three year period for each increment of compost (Mays et

al., 1973). The average Bermuda grass forage yield increased with addition of compost upto a rate of 36 t ha⁻¹. Higher rates of compost addition produced no additional yield increases. Corn yields over two seasons increased with compost additions upto 112 t ha⁻¹ but higher rates did not increase the yield further.

Tietjen and Hart (1968) reported on the effect of municipal composts on yield of crops. Fresh compost reduced potato yields the first year after application whereas ripe compost increased yields of Oat and rye one or two years after fresh compost application. A significant factor, not often observed was that compost increased yields at about a constant rate irrespective of the N added. They observed that the principal use of municipal compost in Europe was for erosion and run off control for which the material was most effective.

Initial nutrient levels of the soil relate strongly to crop response to municipal waste compost applications during the first cropping season. Hortenstine and Rothwell (1972) in their studies with compost applied at rates of 0, 25 and 70 t ha⁻¹ with and without added N, P and K to phosphate mine sand, almost devoid of available plant nutrients, recorded poor plant growth at all levels of compost addition. Poor yields of sorghum and oats were obtained during the first year when no fertilizers to supply N, P, K was added. While

compost alone increased yields during the second year of application much higher yields were produced when N, P, K and compost were applied.

Compost applications at 8.96 and 17.92 t ha⁻¹ increased corn yields in the first year of application with some residual effect on yield at high rates of compost addition to a low fertility soil (King and Morris, 1969).

Hortenstine and Rothwell (1973) reported that compost added at rates equivalent to 8 to 64 t ha⁻¹ increased yields of both the first and second crops of sorghum. However, the compost used had a N content of 2.27 per cent which is more than twice that is found in most municipal composts. With higher rates of compost application, the per cent N, P and K recovered by the crop decreased.

Terman et al. (1973) found that corn grown on a N deficient Mount View (USA) silt loam soil required N additions to compost to prevent yield reduction. However, on a soil containing more available N, compost additions did not induce N deficiency. Nitrogen, phosphorus and potassium in a compost was 16, 71 and 64 per cent effective, respectively for corn as the same amount of these elements when added as chemical fertilizers.

King et al. (1977) observed that grain and total yield of corn were not significantly affected by refuse treatments in 1972 experiments whereas in 1974 the average effect of the three refuse treatments resulted in a 59 per cent increase in grain yield and a 67 per cent increase in total yield as compared to control.

D'Souza and Ramachandran (1984) studied the effect of Bombay City (India) compost applied at 0, 56, 112, 224 and 448 t ha⁻¹ on maize yield under pot culture conditions and reported that city compost significantly increased dry matter yields in the vertisol, whereas in the oxisol, yield differences were only marginal.

2.4.2 Uptake of micronutrients and heavy metals by plants

The availability of metals and uptake by plants are related both to their total concentrations, to their forms and associations in the soil and to a number of physical and chemical factors operating at the soil-root interface. The influence of plant species on the soil-plant relationship may be considerable (Fleming, 1965; Archer, 1971). Different species and indeed different cultivars, regulate metal uptake at both the soil-root and root-shoot interfaces to varying degrees. In general, the trace element content of the whole plant tends to increase with increasing maturity,

and seasonal influences are also important (Fleming, 1965).

Scarcity of landfill sites, high energy requirement for incineration and increasing costs of commercial fertilizers make municipal solid wastes application to agricultural lands an attractive alternative to landfilling as a method for waste disposal. Potential benefits of municipal solid wastes in providing plant nutrients such as N, P, Ca and organic matter have long been recognised (Chang et al., 1978). However, potentially harmful effects and introduction of heavy metals such as Cd, Cr or Hg into the food chain are of concern (Logan and Chancy, 1983). The validity of such concern and ultimately the success or failure of urban solid waste utilization in agriculture depends not only on the properties of the municipal urban solid wastes and loading rates but also on chemical and microbiological characteristics of the soils to which organic solid wastes are applied (Simeeni et al., 1984).

The effect of land disposal of wastes on levels of micro-elements in leaves and edible parts of plants is important because this is the first step in the entry of toxicants in the food chain. However, most organic wastes simultaneously add several metals like Zn, Cu, Cd, Fe etc., and influence soil pH. This coupled with plant differences causes significant variation in plant

uptake of waste borne micro-elements. Generally, certain elements can readily move to plant tops when applied to soil (Mn, Zn, Cd, B, Mo, Se) others with intermediate ease (Ni, Co, Cu) and still others hardly reach the tops (Cr, Pb, Hg). These differences, along with other soil and plant factors strongly influence the translocation of micro-elements to edible plant parts. Because of these findings, there is an increasing interest in using soil as a medium for treatment of municipal wastes.

However, evaluation of the effects of composts on soil fertility is a necessary preliminary task before establishing the real advantages of their use in agriculture (Bauduin et al., 1987).

The feasibility of using land for both waste disposal and crop production was studied by King et al. (1974) by applying pulverized municipal refuse and liquid sewage sludge or liquid manure to land which was later planted for rye and subsequently to corn. Highest corn grain yields were obtained with the 188 m t ha⁻¹. In the other higher rates of addition of refuse the corn yields were not significantly different from control. Levels of Zn, Cu, Cd and Pb in the rye and corn plants were increased by waste additions but were below levels toxic to the crops or to animals that might consume the crops.

Kelling et al. (1977) reported that the addition of sludge increased the concentrations of Cu, Zn, Cd and Ni in the vegetative tissue but except for Zn, the additions had relatively little effect on the metal content of corn grain. Chromium did not accumulate in the leaf tissue or grain. In all cases, concentrations of metals were below levels toxic to crops. Levels of DTPA extractable Cu, Zn, Cd and Ni but not Cr increased in soil with sludge treatments. Regression analysis showed that DTPA extraction might be useful for predicting the uptake of heavy metals by the vegetative portions of the plant. The decrease in metal concentrations in the plant tissue and in DTPA extracts with successive crops indicated reversion to less mobile for Zn, Cd and possibly Ni.

King et al. (1977) stated that there was no effect of refuse treatments on Cr and Ni levels in the corn grain or stover. Iron was not affected in the stover but grain levels were increased at 188 and 376 t ha⁻¹ refuse treatments. Copper levels in the grain were unaffected by treatments. Only the treatments containing refuse increased Cu levels in the stover each year. Uptake of Cu was increased at 376.0 t ha⁻¹ refuse treatment in 1972 experiment. Similarly manganese levels in the grain were either not affected or reduced by the waste treatments. The Mn level was increased in

stover with 376 t ha^{-1} refuse treatment. All the treatments did not affect grain Pb. However, Zn levels were increased in stover by all treatments containing refuse. Only Cu, Cd and Zn concentration were consistently affected by treatments, mainly in the stover. Cadmium concentration in the stover exceeded the level of 0.5 ppm for food stuffs at 376 t ha^{-1} refuse treatments. They concluded that the increased availability of heavy metals (as measured by uptake) with treatments containing refuse was consistent with Pb, Zn and Cd.

Spittler and Feder (1979) studied growth and Pb uptake of plants in garden soils containing a range of Pb levels (100-2000 ppm). There was a positive correlation between soil Pb and plant uptake although uptake varied with the plant species (fruit crops, root crops and leafy vegetables). Plant tops contained a higher Pb concentrations than roots.

Haan (1981) stated that the zinc content of crops in a range of compost soil mixture increased with increasing compost soil ratio and crop growth was greatest in 100 per cent addition of compost to soil (W/W).

In a greenhouse experiment, Nogales et al. (1985) reported that application of compost increased zinc concentration and zinc uptake by rye grass.

Cottrell (1975) stated that some beneficial fertilizer effect was obtained from P, Zn and Cu in the refuse materials but quantities of boron which could be detrimental to sensitive plants were also added at all rates of solid waste application. Large quantities of the micro-nutrients, Zn, Cu and B as well as Na, were added to the soil with waste addition such as zinc and B uptake by wheat and fescue approached or exceeded toxic levels during the first growing season. The trace element toxicities were reported to diminish after the first growing season. Elements such as Zn, Cu, Mn and Mo were apparently immobilized in the soil while excess Na was leached from the surface and distributed throughout the soil profile. Zinc and Mn uptake by the fescue remained high only where soil pH had decreased to less than 6.0 following heavy applications of ammonium sulphate fertilizer. The Zn and Mn contents of the waste treated soil lead to toxicity problems in acid soils.

King et al. (1974) stated that rye plants grown for 9 months on Guelph (Canada) loam soil treated with municipal compost at a rate of 188 t ha^{-1} contained about 70 per cent more Zn than control plants. Corn was planted after rye without further additions of compost. Both corn grain and stover contained 50 to 100 per cent more Zn in treatments where refuse was applied.

Chu and Wong (1987) studied the heavy metal contents of vegetable crops grown on loamy sand soil treated with at 25, 50, 75, 100, 125 and 150 t ha⁻¹ of refuse compost in pots and sown with Brassica chinensis (mustard), Daucus carota (carrot) and Lycopersicon esculcutum in glasshouse. The results revealed that crop yield in refuse compost treatment was improved over that in sandy soil alone, but was less than that in the fertilizer treatments. Further they stated that despite the relatively high heavy metal contents of refuse compost, crops grown on compost treated soils accumulated lower levels of metal than those grown on sludge treated soils. They attributed this to the high pH and organic matter status fo the composted refuse. The heavy metals were found in the roots than in the aerial parts of mustard and tomato but the reverse was found in carrot. It was concluded that in the edible tissue of the three crops, tomato accumulated metals to a lesser extent than the other two.

Petruzzelli et al. (1989) reported results of a four year field experiment on the influence of repeated refuse compost additions at the maximum rate allowed by Italian legislation (30 t ha⁻¹ yr⁻¹), On the transfer of heavy metals from the soil to a corn crop and the mobility of these elements in the treated soil. The results showed that the cadmium in corn plants increased

particularly in the roots from 0.22 to 1.31 mg kg⁻¹. Concentration of Zn and Cu increased in grains from 26.8 to 35.8 and from 2.4 to 4.2 mg kg⁻¹, respectively. Relevant increase in the roots was detected for Zn from 34.6 to 146.8 mg kg⁻¹ only in the fourth year Ni concentrations increased in the root portion while the content of Pb and Cr in corn were generally unaffected by compost application.

Reddy et al. (1989) conducted a field study to determine uptake and distribution of Cu and Zn by soybean (Glycine max. L. Merr) and corn (Zea mays L) grown on a sandy loam (fine mixed, thermic ultic Haplustalts), treated with 0, 25, 50 and 100 mg ha⁻¹ of sewage sludge each year. Soybeans were grown in the first year and corn in the second year. In general, sludge significantly increased grain yield of soybean and corn. Copper concentration in soybean seed was higher than in leaf and stem but Zn concentration was lower in the seed than in the other tissues, under sludge treatment. Copper in corn leaf increased more than in stem and grain as the rate of sludge addition increased. Zinc content increased in corn leaf and stem as the rate of sludge increased while Zn content in grain was not affected.

D'Souza and Ramachandran (1984) studied the uptake of Fe, Mn, Cu, Zn, Co, Pb, Ni, Cd and Cr by maize

(Zea mays L.) grown on a laterite soil (Oxisol) and medium black soil (vertisol) treated with different doses (0, 56, 112, 224 and 448 t ha⁻¹) of city compost from Bombay (India). The results revealed that city compost increased zinc concentration in plants with higher doses in both the soil types. Significantly higher concentration of Cu, Co, Pb, Ni and Cd in plant were obtained in compost treated oxisol but not in vertisol. Uptake of Cr was unaffected Mn and Fe concentration in maize shoots were significantly reduced in the oxisol with the addition of compost but not in the vertisol. The DTPA extractable Zn, Co, Cd and Mn levels in amended soils correlated well with their respective concentrations in maize. Besides, the data revealed appreciable residual levels of DTPA extractable heavy metals in soils after crop harvest indicating their availability to succeeding crops

The existing knowledge on the effect of urban waste in plant uptake of microelements clearly indicates that some elements such as Zn, Mn and Cd are absorbed more with increasing application of wastes. In case of copper, increased uptake by plants occurred with lower doses of application of compost or sewage sludge which reached a plateau. Nickel uptake also behaved similarly whereas Pb uptake decreased. Concentrations of Hg in plants remained unaltered, whereas for the other microelements like Se, Mo, As and others, not sufficient data

are forthcoming to draw valid conclusions about their uptake. Increased uptake of Cd and Pb with applications of organic residues like urban waste compost or sewage sludge should be viewed seriously because of their potential health hazard once they enter the food chain (Lagerwerff, 1972 and Braude et al., 1975).

2.5 UTILIZATION OF ORGANIC WASTES ON AGRICULTURAL LAND

Land disposal of organic wastes add micro-elements to the soil because nearly all refuse contains higher levels of micro-elements than those present in soils. There is a sustaining interest to study the long term effects of waste applied micro-elements on soils and plants. Some micronutrient elements (Zn, Cu, B, Fe) in wastes may serve to correct plant deficiencies. Alternatively, repeated or unregulated use of wastes might lead to phytotoxicities of Zn, Cu, Ni or B. Further, certain non-nutrient heavy metals (Cd, Pb, Hg) present in some wastes are of concern to agronomists, nutritionists and environmentalists because of the hazard to man and animal health when they gain entry into the food chain through soil.

Although the correction of micro-nutrient deficiencies has become a routine agricultural practice, the study of potentially phytotoxic additions of micro-

elements is a young science. Research on the micro-nutrients has provided much information on the waste, soil, plant, animal relationships of some of these elements. However, little is known about many of the factors controlling these relationships at high levels. It should also be ensured that the apparent economic saving for farmers gained by land application of wastes does not become an environmental or fertility problem for the future. Most of the identified potential problems from waste borne micro-elements can be avoided by judicious management through proper selection of wastes, soils and crops and proper reliance on soil and plant testing.

2.5.1 Correction of plant micronutrient deficiencies

Plant deficiencies of Zn and Fe are commonly observed in India and deficiencies of Mn, Cu, Mo and Co are occasionally found. Kubota and Allaway (1972) described the geographic distribution and soil properties related to micronutrient deficiencies. Many aspects of the use of micro-nutrients in agriculture were reviewed (Mortvedt et al., 1972) including climatic and soil conditions which influence deficiencies (Lucas and Knezek, 1972), crop differences in micronutrient requirements (Brown et al., 1972) and the use of micronutrient fertilizers as soluble inorganic compounds or soluble metal chelates. Micronutrient

fertilization has been increasing world- wide due to the intensification of agriculture. As most elements added through micronutrient fertilizers are present in varying proportions in organic wastes such as municipal solid wastes, sewage sludge, farm wastes and others, it is appropriate to review the importance of these wastes as sources of micronutrients for crops.

The concept of using organic wastes to correct micronutrient deficiencies is linked to the potential of these wastes to cause toxicities. Any waste which contains enough of an element to cause toxicity if used in excess, could be considered a fertilizer if applied at lower rates to correct a deficiency of that element. Thus, wastes may be used to correct Zn, Cu and possibly B, Mn and Fe deficiencies. At equivalent rates of Zn application organic wastes were as effective as ZnSO_4 in correcting zinc deficiency of corn but the ashes of the wastes were ineffective. At higher application rates, the activated sludge produced phytotoxicity. This commonly occurs when raw activated sludge is applied at rates exceeding the N requirement (Mortvedt et al., 1972).

The potential use of organic wastes as Fe fertilizers is especially attractive because inorganic

Fe is seldom effective except at high rates (Hodgson et al., 1972; Mortvedt and Giordano, 1973) and synthetic chelates of Fe are expensive to use.

Lindsay and Park (1970) compared the ability of refuse compost (4.75% Fe) activated sludge treated with lime and Fe Cl_3 (1.98% Fe), and Fe-EDDHA to correct Fe deficiency of sorghum grown on a calcareous clay loam. They also compared FeSO_4 additions in the presence and absence of organic wastes. Addition of FeSO_4 to the refuse compost increased yields well beyond levels obtained with FeSO_4 alone, atleast for the first crop.

Whether organic wastes can be safely used to correct Fe deficiency remains uncertain. The wastes vary widely in Fe content and chemical form. According to Brown and Jones (1975) other heavy metals (Zn, Cu etc.) in some organic wastes may eventually accentuate Fe deficiency, even though the deficiency is temporarily corrected.

It has been experimentally demonstrated that manure and composted refuse can be used to correct Zn and Cu deficiencies and they may alleviate Fe deficiency. Application of high rates of unleached refuse and refuse compost can cause B deficiency (Chaney et. al., 1974).

Use of a waste to add both macro-nutrients and needed micro-elements depends on its composition. It seems reasonable that wastes which are otherwise safe for use on crop land, could be applied to satisfy N or P requirements and the waste could simultaneously correct any Zn, Cu and other micronutrient deficiencies. Application of 10 t ha^{-1} of domestic sewage sludge could add 200 kg Fe, 25 kg Zn, 10 kg Cu, 5 kg Mn, 0.5 kg B and $0.05 \text{ kg Mo ha}^{-1}$. Although excessive applications of the same organic wastes could lead to micro-element induced phytotoxicity, use of low rates could supplement use of inorganic micronutrient fertilizers (Chaney et al., 1974).

The mechanism whereby organic wastes correct zinc deficiency is unclear, although the simple addition of the waste containing Zn could account for this correction. On the other hand, Miller and Ohlrogge (1958a, 1958b) and Tan et al. (1971) have characterized zinc chelating organic materials present in manure and sludge. From the work of Parsa (1970) it was clear that ash of an organic waste is less effective as Zn fertilizers. This work indicated that zinc added through organic waste was more available to corn than soluble inorganic Zn. Studies on acid soils have usually shown that soluble inorganic Zn is more available to plants than Zn in digested sewage sludge or composted refuse

(Giordano et al., 1975; Mortvedt and Giordano, 1975; Giordano and Mays, 1976; Cunningham et al., 1975). Wastes relatively high in Zn, such as sewage sludge or composted refuse are better Zn fertilizers than most animal manures.

2.5.2 Phytotoxicity from micro-elements in organic wastes

The accumulation of phytotoxic levels of micro-elements in the soil from repeated applications of metal rich wastes is of serious concern threatening the practice of ultimate disposal of urban wastes on agricultural land. Application of domestic wastes at very high cumulative rates, or application of wastes enriched in metal by mixing with industrial wastes containing such metals would lead to large increases in micro-elements in soils. Because removal of most of these micro-elements by cropping would be slow, their accumulation presents a long term potential for phytotoxicity. Phytotoxicity is dependent on management factors such as soil pH and crop species and high accumulations of some waste-borne micro-elements could require more intensive management of these factors than is ordinarily practised.

Phytotoxicity and induced Mn deficiency (Trocme et al., 1950) and induced Fe deficiency (Rohde, 1961; 1962) on the Paris (France) and Berlin (Germany) sewage

irrigation farms were reviewed. Metal sensitive vegetable crops were severely injured.

Blood (1963) described a sewage irrigation farm in Great Britain where 500 ppm Zn had accumulated in the surface 25 cm of a sandy soil and sugar beet yields were reduced in patches where the soil pH had fallen below 6.4. Liming provided partial recovery. Spotswood and Raymer (1973) described a sewage irrigation farm converted to a sludge disposal farm where very high levels of total Zn (400-1,300 ppm in soil) and total Cu (50-300 ppm) were found. The average soil pH was 6.2 but some samples were as low as 5.0. Of the 875 ppm total Zn, 270 ppm were extractable with 0.5 N acetic acid. Attempts to grow sugarbeet failed.

Patterson (1971) observed instances of crop damage caused by the build up of toxic levels of one or more metals in the soil usually after dressing of sewage sludge, repeated over a number of years.

In field experiments with sludges high in metals (Webber, 1972, 1974) lettuce (Lactuca sativa L.) and redbeet failed where 112 m t ha⁻¹ of a sludge containing 8,000 or 16,000 ppm Zn was applied to a pH 6.4 gravelly silt loam. Damage was more severe during the second and third years than the first. In a field experiment with a low metal sludge in Georgia (USA), rye

was injured but Bermudagrass was not; the soil pH fell to 4.2 and Zn and Cu were implicated in the phytotoxicity (King and Morris, 1972).

2.5.2.1 Zinc toxicity: Some soils contain abnormally high levels of zinc. Plants growing on such soils often show signs of zinc toxicity, though in some cases a distinct flora develops which is capable of growing and completing its life cycle in such conditions (Antonovics et al., 1971), the general symptoms of zinc toxicity is a retardation of growth, plants being stunted and chlorotic. Takkar and Mann (1978) described zinc toxicity symptoms in wheat and maize, light blue green tinge develops at the leaf tips and spreads to the base, older leaves are chlorotic, finally the leaf dries out. These symptoms are similar to those of P toxicity. Associated with these symptoms are the concentration of Zn in plant. Further they reported that 7 ppm DTPA extractable soil Zn was toxic to wheat and 11 ppm to maize. The tissue levels at these soil levels were 60 and 81 ppm respectively. Somewhat higher levels have been recorded by Beckett and Davis (1977) and Davis and Beckett (1978) for barley and ryegrass respectively. About the upper critical level of zinc, the yield was found to decrease approximately in proportion to the logarithm of the tissue concentration.

2.5.2.2 Copper toxicity: Most of the concern over Cu in organic residues stems are proposals to use relatively high levels of Cu (> 200 ppm) in rations for some animals like hogs for growth stimulation or antibiotic effects (Underwood, 1971). Incorporation of manure from pigs fed on Cu supplemented feed into the soil did not consistently increase the Cu concentration in forage grasses.

The Cu concentration in municipal sewage sludges is reported to range between 250 and 17,000 ppm (Chaney, 1973; Page, 1974) with usual average being round 1,000 ppm. Thus, the Cu concentration in municipal sludges approximates maximum values expected in manure from Cu-supplemented pigs. Copper concentrations in crops produced on lands treated with municipal sludges have not been elevated to levels indicative of a hazard from Cu toxicity to consumers of the plants (Peterson, 1975). Phytotoxicity of Cu will ordinarily inhibit plant growth before Cu concentrations in this range would be found in plants (National Academy of Sciences, 1974). Ruminants, especially sheep are more susceptible to Cu toxicity and may be adversely affected by dietary Cu concentrations found in plants growing on Cu-polluted areas.

Application of Cu through organic wastes may help to prevent Cu deficiency in plants and possibly in

animals but is not a refined or well defined method of correcting these deficiencies. Use of contaminated sewage sludge as a soil amendment can be responsible for introduction of excess copper to farm land. In some countries like USA, guidelines have been developed to regulate the extent of this practice (Chumbley, 1971).

Copper toxicity in plants is generally manifested as a general chlorosis and stunting of growth (Foy et al., 1978). The chlorotic condition may result from iron deficiency, as foliar application of inorganic FeSO_4 (Hewitt, 1953) or soil application of iron chelates (Leonard and Stewart, 1952) can alleviate this condition. Analysis of foliage from such chlorotic plants revealed a low iron content (Smith et al., 1950; Roth et al., 1971). The extent of copper induced iron chlorosis may be affected by climatic and other soil conditions not connected with copper toxicity (Lucas and Knezek, 1972).

Copper toxicity can reduce root growth and penetration into the soil (Foy et al., 1978), toxicity during early growth period of plant occurring in root tips (Brams and Fiskell, 1971; Daniels et al., 1972) with subsequent inhibition of the development of lateral roots and consequent growth inhibition.

In some soils excessive levels of copper may be present without adversely affecting plant growth

(Dykeman and de'Sousa, 1966). The lack of toxic effect in such cases is due to the interaction of copper with other soil factors; for example, a very high soil organic matter content served to immobilize the excessive copper levels due to strong binding.

2.6 HEAVY METALS IN SOILS AND PLANTS

2.6.1 Lead (Pb)

The presence of indigenous lead in the earth's crust at concentrations averaging 16 ppm in soil (De Treville, 1964) and the knowledge that lead is highly toxic to various physiological processes have brought into focus over the last two decades the question of the effects of lead on higher plants and the consequences of the heavy metal entering the food chain.

In recent years, human activity has caused increased concentration of Pb in agricultural lands due to application of sewage sludge and mining wastes.

Lead is available to plants from soil and aerosol sources. The actual uptake and association of lead with plants is affected to varying degrees by almost all environmental factors (Koeppel, 1980). The lead incorporated into soils is nearly always tightly bound to organic or colloidal fractions or in a precipitated form all of which serve to reduce the uptake of

lead into plant roots. These observations are supported by experiments which show that increased cation-exchange-capacity (Baumhardt and Welch, 1972; Miller et al., 1975), lowered pH (Cox and Rains, 1972; Zimdahl and Foster, 1976) organic matter (Liebhardt and Koske, 1974), phosphorus (Sung and Jeong, 1977) and other lead precipitating anions (Sung, 1976) reduced the uptake of lead into plant roots.

Application of organic solid wastes to land has nearly always decreased the Pb content of plants. Hinesly et al. (1972) and Chaney et al. (1975) found that low levels of sewage sludge slightly increased while higher sludge levels decreased plant Pb, especially in grain, fruit or edible roots. Liebhart and Koske (1974), Giordano et al. (1975) and King et al. (1974) found lower plant Pb with additions of refuse compost. Jones and Hatch (1945) found that many plants grown on soils contaminated with Pb arsenate increased only slightly in Pb, but levels in egg plant fruit rose to 35 ppm. Jones et al. (1973) found that S deficiency allowed more Pb to reach plant tops. Miller et al. (1975) found that Pb uptake by corn and soybeans was negatively correlated with soil pH and CEC. Baumhardt and Welch (1972) added upto 3,200 kg Pb ha⁻¹ to a soil with pH 5.9 and reported that although foliar Pb content increased, grain was unaffected.

Davies and Roberts (1975) grew radish in gardens in an area heavily polluted by cadmium, lead and zinc from old mine workings and reported that in radish, from three out of seventeen plots the British legal limit for lead of 2 ppm (fresh weight) was exceeded.

Marten and Hammond (1966) grew brome grass on lead contaminated soils in a glasshouse and found no difference between plants growing on soils containing 12, 59 and 95 ppm Pb, but at a soil level of 680 ppm Pb Brome grass did contain significantly more of the metal. Moreover, it is commonly found that much of the lead absorbed by a plant is retained in the roots and the movement upwards is restricted.

MacLean et al. (1969) grew oats on four soils pre-treated with PbCl_2 and found the uptake reduced by increasing soil pH, higher phosphate and soil organic matter levels.

When roots are treated very little lead is translocated into edible parts like fruits and grain (Koeppe, 1977).

Koeppe (1980) reported that most of the lead is associated with the roots and little with the plant tops. It is often very difficult to compare the total amount of lead treatment with the roots of plants and herein lies the probable quantitative differences in

lead affected plant response. In an experiment, lead salts have been incorporated into a number of different soils. Neither alfalfa nor corn were affected by lead concentrations upto 212 ug g^{-1} in a Chester silt loam soil (Lagerwerff et al., 1973). Soybean (Glycine max L.) and corn (Zea mays L.) were sown in a sandy clay soil and watered with fixed concentrations of lead and various anions (Sung and Jeong, 1977). When the plants were harvested before flowering they showed no signs of lead toxicity inspite of $3773 \text{ ug Pb g}^{-1}$ soil. Total lead concentrations in the plants did not exceed 3.64 ug g^{-1} dry weight. In another study with 500 ug/g Pb in the soil, radish, carrot and spinach absorbed considerable quantities of lead but without reducing yield or showing toxicity symptoms (Judel and Stelte, 1977). Karamanos et al. (1976) recorded no yield reduction in alfalfa and brome grass grown on soils amended with upto $100 \text{ ug Pb}^{-1} \text{ g}^{-1}$ soil. In many of the studies the defined presence of anions such as phosphate and sulfate reduced the uptake of lead.

One of the most significant applications of lead to agricultural soils has been with numerous other heavy metal and other major and minor micronutrients in organic wastes. With the ever present possibility that a number of these metals besides lead might be toxic to plants, it has not been possible to isolate any distinct lead effects from such organic waste applications. In

actuality, the presence of many other competing ions probably serves to reduce the uptake and the subsequent ill effect of lead. Several studies have questioned, however, whether combinations of heavy metals that are known to be toxic to plant might at certain concentrations act synergistically or antagonistically. Miller et al. (1977) reported that the effect of the two heavy metals together (Pb and Cd) was greater than the sum of the effects of the individual heavy metal treatments.

As a result of observations of the uptake and effect of lead on the growth of plants in the field and the literature cited here, along with many other studies too numerous to list here, the following concepts have emerged. First, that lead is taken up by plants with the magnitude of uptake being correlated inversely to soil or other artificial rooting-media conditions that bind lead : Such binding of lead reduces its activity in the soil or in the rooting medium. Good agricultural practice in monocultural or natural system should virtually negate the uptake and effect of lead under field conditions. In the absence of agricultural disturbance, it seems that Pb uptake from the soil would be found only under conditions where the soils were light and had low fertility levels, low organic matter content and/or a low cation exchange capacity. Even here, where some lead uptake is likely, studies have shown that 90 per

cent or more of the lead taken into roots is tightly bound there, not available for translocation to other parts of the plant and not toxic to plants. The chances that enough lead can be taken up by any higher plant under natural conditions to effect a toxic response seems remote. (Koeppel, 1977).

2.6.2 Nickel (Ni)

According to Swaine (1955), soils normally contain 5 to 500 ppm Ni with an average of about 100 ppm. Mitchell (1945) divided soils into two groups (1) those derived from sand stones, lime stones or acid igneous rocks, containing less than 50 ppm Ni and (2) those soils derived from argillaceous sediments or basic igneous rocks, containing 5 to more than 500 ppm of nickel. Serpentine soils can also contain upto several thousand ppm of nickel. It is apparent from the literature that the availability of nickel for plant uptake varies quite markedly between soils and is also plant species specific.

Generally, additions of nickel from sewage sludge, even though much of it is organically bound, leads to an increase in both root and shoot levels of nickel in a wide range of crop plants (Anderson and Nilsson, 1972; Page, 1974; MacLean and Dekkar, 1978; Soon et al., 1980). The soils suited to receive nickel contaminated sewage sludge with a minimal effect on

plant uptake of nickel are those of neutral to alkaline pH and with a high organic matter content.

Even in any one soil, the nickel uptake and concentration in plant foliage can differ markedly between species. Hutchinson and Whitby (1974) reported concentrations of 902 ppm Ni in the grass Deschampsia flexuosa and 92 ppm Ni in the foliage of Vaccinium angustifolium at the same site. Nitric-perchloric acid extractable nickel in surface soils was 1950 ppm at this site. Peterson (1975) also emphasised species differences in nickel uptake were reported showing Silene maritima to have 328 ppm Ni in its foliage compared with 1780 ppm Ni in Silene acaulis growing on the same serpentine soil in the Shetlands (Canada). In another report Shewry and Peterson (1975) found that levels of nickel in the roots of plants grown on these soils approached or exceeded the soil nickel concentrations.

While both plant foliar and root levels of nickel are generally lower than those in soils, marked exceptions occur with accumulator species, of which a substantial number are described. Brooks and Crooks (1980) described the excellent correlations observed between soil nickel and nickel in the foliage of the nickel accumulator species Lychnis alpina from Europe. On soils high in nickel, the foliage had nickel levels upto twice those of the soil concentrations.

Severne and Brooks (1972) and Severne (1974) described the nickel accumulator Hybanthus floribundus from Western Australia, which had a plant soil ratio as high as 163.

McIveen and Balsillie (1977) reported on metal concentrations, including nickel, in fruits and vegetables grown in the Sadbury area, Ontario, Canada. The edible parts of such locally grown vegetables as radish, carrot, beet or potato contained less than 20 ppm Ni. Tomato and cultivated fruits had levels of 9-15 ppm dry weight and < 5 ppm respectively.

Hutchinson (1978) reported that in plots established close to a smelter, bean pods contained from 23 to 96 ppm Ni dry weight, compared with 6 ppm at a control site, radish contained 18 to 74 ppm Ni, compared with 21 ppm at the control site.

Hutchinson et al. (1974) analysed crops and soils from a major horticultural area developed on deep organic muck soils. At the time of harvest, concentrations of Ni in lettuce, cauliflower, onion, potato, carrot and parsnip foliage ranged from 2.8 to 6.2 ppm. Keeney and Walsh (1975) obtained values of 0.9 to 2.5 ppm Ni for rye, sorghum and corn grown on unamended agricultural soils, while Bates et al. (1975) found levels of 2.7 to 3.2 ppm Ni in rye grass before sewage sludge additions to the soil.

The nickel concentrations in plants grown on soils other than those with excessive nickel levels are usually low and measure less than 10 ppm.

2.6.2.1 Nickel toxicity: The toxic properties of excessive nickel in soils for plant life was first pointed out by Haselhoff (1893), who demonstrated its toxicity to corn and bean plants using solution culture techniques. Since then, a large number of reports of nickel phyto toxicity have been made. Most describe poor growth accompanied by chlorosis. Wolff (1913) found that 8 ppm Ni in solution rapidly killed barley. Cotton (1930) found that 0.5 ppm nickel produced chlorosis in buck wheat. Brenchley (1938) reported 2 ppm Ni to be toxic to bean and barley. Flax (Linum usatatisissimum) was found to be especially sensitive, showing toxicity at 0.5 - 5.0 ppm (Millikan, 1949).

Vanselow (1966) provided an extensive compilation of data on Ni toxicity from the literature, which showed that for most crop plants the nickel content of foliage is < 2 ppm of dry weight. Tissue concentrations of greater than 50 ppm could be considered excessive. Toxic symptoms of nickel showed in young citrus plants containing 55 ppm Ni in leaves. Halstead et al. (1969) found a decrease in growth of oats when the nickel content of the grains exceeded 60 ppm and of the straw

28 ppm. Alfalfa showed a decrease in growth when foliar levels exceeded 44 ppm.

The symptoms of nickel toxicity appear to be a combination of induced iron-deficiency chlorosis and foliar necrosis. Mishra and Kar (1974) described the main toxic symptoms of nickel as chlorosis or yellowing of the leaves, followed by necrosis. Other toxic symptoms include stunted growth of the roots and shoots, deformation of various plant parts and unusual spotting on leaves and stems. Vanselow (1966) pointed out that in monocotyledons nickel toxicity often showed up as alternate green and light yellow banding on the leaves, while in dicotyledons the symptoms are of a general chlorotic mottling.

Monitoring of Ni levels in sewage sludge and in crops grown on sludge treated areas is highly desirable, because it is reported by Page (1974) that Ni concentrations in sludges reach 3000 ppm or more and cites evidence that plants grown on sludge-treated soils are substantially higher in Ni than controls. In analyses of root and shoot of seedlings of radish, cabbage, tomato and lettuce grown in water extracts of polluted soils from smelter in Ontario, Canada, whole seedling nickel concentrations of upto 1050 ppm occurred and in inorganic nutrient solution, with nickel added at 0, 1, 5, 10, 15 and 20 ppm, root concentrations of 50, 270,

480, 3750, 9800 and 20580 ppm occurred (Whitby and Hutchinson, 1974). This massive uptake proved to be lethal.

2.6.3 Cobalt (Co)

In the earth's crust, the average concentration of cobalt is 23 ppm (Mason, 1966). In terms of abundance, it is ranked 32nd of all the elements and 19th of the trace elements. Cobalt, like iron, forms two normal valence states, cobaltous (Co^{2+}) and cobaltic (Co^{3+}) ions and compounds and a few cobaltites, derivatives of the dioxide CoO_2 . The cobaltic ion is a very powerful oxidizing agent and for this reason its compounds are not very stable, except those complexes which have very small concentrations of the metal ion. The cobaltous ion is, therefore, the more stable form.

The total cobalt content of soils is usually within the range of 1-40 ppm according to Swaine (1955) although Thornton and Webb (1980) quote a wider range of 1-100 ppm for normal soils. Total contents of 20-100 ppm cobalt are found in soils derived from basic igneous rocks or argillaceous sediments, whereas contents below 20 ppm are normal in soils derived from sand stones, lime stones and acid igneous rocks (Mitchell, 1945). Mean soil cobalt values reported are 8 ppm (Bowen, 1966) and 10 ppm (Brooks, 1972). No positive correlation has been shown between total cobalt in soils and the amount

of cobalt in plants (Alban and Kubota, 1960) but highly significant correlations for EDTA and acetic-acid extractable cobalt and the cobalt content of plants have been found over a range of soil series (Mitchell et al., 1957; Alban and Kubota, 1960; Rana and Ouelletto, 1968).

The cobalt content of various plant species, when grown under the same conditions vary markedly. In general, legumes, cereal forages and most weeds are high in cobalt but grasses and underground portions of vegetables are relatively low in cobalt (Mitchell, 1945; Hill et al., 1953; Kubota and Allaway, 1972). For example, lucerne, clovers and lupins contained 0.3 - 0.4 ppm cobalt when grown on the same soil with a 17 ppm cobalt content.

A variety of factors affect the cobalt status of plants. Soil composition, including levels of elements such as manganese and iron, soil moisture and pH and plant factors such as stage of growth, plant species and type of organ examined are the main factors involved (Kubota, 1965; Handreck and Riceman, 1969; Gille and Graham, 1971). Reports of McKenzie (1975), Norrish (1975) and others clearly indicate that the most important factor in the chemistry of soil cobalt and its availability to plants lies in its association with the manganese oxide minerals. Soil pH is probably the next

most important single factor in determining levels of soluble cobalt.

Mean plant accumulation of cobalt varied from species to species (Lyon et al., 1971). The ratios of mean plant ash concentration to mean soil concentration ranged from 0.27 for Myosotis mouroi to 0.87 for Pimelea suteri.

Vanselow (1966) reported that cobalt produces toxicity to plants when the amounts available exceed certain limit. But that a naturally occurring excess was apparently not toxic. For example Nyssa sylvatica can contain thousands of ppm cobalt in their leaves yet show no toxicity symptoms, whereas, as low a leaf content as 11 ppm in citrus plant produced marked growth depression and chlorosis resembling iron deficiency. Fujimoto and Sherman (1950) found cobalt toxicity in Sudan grass at 19-32 ppm (dw) when grown on soils fertilized with excess cobalt.

2.6.4 Cadmium (Cd)

Increases in plant Cd from sewage wastes and refuse applications on crop land is a major issue in the safety of land disposal. There have been several studies on the microelement content of crops growing on fields where sewage wastes have been applied for many years as compared to nearly control fields. Anderson

and Nilsson (1972) found no increase in Cd in rape fodder after 15 years of sludge utilization. Likewise, Chaney et al. (1972) found no increase in Cd in the pasture grasses where sludge was applied for 24 years. These studies involved use of low Cd sewage or waste water.

Kirkham (1975) analyzed corn plants growing on a sludge disposal farm at Dayton, Ohio. The soil Cd had increased from 2 to 50-70 ppm. The Cadmium in corn leaves increased from 2.1 to 14 and 24 ppm but in the corn grain increased only from 0.8 to 0.9 and 1.0 ppm in sludge treated and supernatant treated areas as compared to Cd concentration in control soil.

Field experiments have generally shown that plant Cd levels increase with sludge, refuse compost or waste water application. Jones et al. (1975) applied high Cd sludge and observed large increases in corn foliar Cd (0.5 to 20 ppm Cd) and corn grain (< 0.1 to 1.00 ppm Cd). Soybean grain Cd levels exceeded 3 ppm on some of their plots. Dowdy and Larson (1975) found 2 to 4 fold higher levels of Cd in nearly every crop tissue from large applications of a domestic sludge, however, pea pod and corn grain levels remained low.

Giordano et al. (1975) found that Cd in sweet corn grain had increased from about 0.3 to as high as 1.2 ppm Cd. They found that repeated application of

waste-borne Cd did not lead to a proportional increase in foliar or grain Cd levels (Giordano and Mays, 1976). Refuse and refuse sludge mixtures increased Cd in rye and corn leaves (King et al., 1974). Levels in corn grain were unchanged. Refuse sludge compost application raised corn stover and grain Cd (Giordano et al., 1975).

A number of greenhouse studies on the effect of sludge Cd additions on Cd uptake by crops have been reported. John et al. (1972) found that Cd adsorption capacity, exchangeable Cd levels, soil pH and soil organic matter content were significantly related to Cd uptake by oats from cadmium amended soils.

Haghiri (1974) grew soybean in a soil amended with 10 ppm Cd and with 0 to 400 ppm Zn. Low Zn additions increased Cd in the tops, while higher Zn additions markedly reduced Cd in the soybean tops. These results with dicots indicate that high Zn/Cd ratios in organic wastes would tend to restrict increases in plant Cd.

In Japan, rice grain Cd levels were implicated in "itai itai" disease of humans (Yamagata and Shigematsu, 1970). Considerable research effort was focussed on amendments or management techniques which might reduce Cd uptake by rice, although rice has

actually much lower Cd than other crops grown on these soils.

Takijima and Katsumi (1973) found that soil pH and Eh were important controls on Cd uptake. Low soil pH favoured uptake, while reducing conditions hindered uptake. Lime amendments and maintaining anaerobic soil conditions during grain filling by irrigation could reduce grain Cd to acceptable levels.

Urban wastes generally increase crop Cd levels. Baker and Chesnin (1976) discussed the movement of Cd into the food chain. It appears that increases in crop Cd can be kept low by excluding Cd wastes from sewers.

More research efforts probably been directed towards Cd than towards any other trace element in municipal sewage sludge.

Current background levels of Cd are about 0.05 to 0.40 ppm in human diets and the average daily human intake of Cd is probably 40 to 150 $\mu\text{g day}^{-1}$. Cadmium intake of people affected by itai-itai disease may have been 600 to 1000 $\mu\text{g day}^{-1}$.

The ratio of Zn to Cd in plant material grown in unpolluted areas and in human diets is usually in the range of 100 to 1. Under some circumstances, Zn competes with Cd in uptake and translocation process in plants. The concentration of Cd in the edible seeds of

fruits generally is lower than in leafy vegetables. The concentration of Cd in the kernels of corn (Zea mays L.) has been especially low, even when the corn is grown in soils treated with heavy rates of high Cd sludge (Chaney, 1973). Procedures for minimizing hazards from Cd have been described by Chaney (1973). Adjustment of Cd/Zn ratios in wastes to keep the level of Cd at less than 0.5 per cent of the Zn, selection of finer textured neutral or alkaline soils as disposal sites, regulation of annual and total application rates and cropping the disposal site to corn used for grain are measures that help to minimize the hazard to food chains from Cd contained in sludges.

2.6.5 Chromium (Cr)

Chromium is one of the most recent additions to the list of elements essential in the nutrition of man and animals. The nutritionally effective form of Cr appears to be an organic complex of currently unknown structure. The Cr in leafy plants has not been found to be nutritionally effective and seed crops, especially wheat contain very low levels of Cr (Welch and Cary, 1975). The status of research on Cr in plant nutrition has been reviewed by Mertz et al. (1974).

In view of the limited possibility for hexavalent Cr to be present in organic materials, it appears

that Cr in these sludges present no hazard to food chains and it will not be effective in improving the nutritional quality of plants by increasing their content of nutritionally effective forms of Cr.

The distribution of chromium in the environment and its biological effects have been well reviewed in the National Academy of Sciences, USA publication entitled Chromium. In the earth's crust chromium is fairly abundant, ranking fourth among the 29 elements of biological importance and is more abundant than many essential elements including cobalt, copper, zinc, molybdenum, nickel, lead and cadmium (Baetjer, 1974).

Henna and Grant (1962) recorded chromium concentrations in shrubs and trees from 0.2 to 0.6 ppm (dw) which encompasses the mean plant value of 0.23 ppm calculated by Bowen (1966). Lichens and mosses accumulated more chromium than the leaves of higher plants (Lounamaa, 1956). In general, leaves and stems contain less than 1 ppm Cr (dw) when grown on a normal soil although species differences have been recorded (Cary et al., 1977). Spinach and maize leaves, for example, contain 4.6 and 10 ppm chromium, respectively (Renan et al., 1979). Peterson and Girling (1980) showed that chromium was not distributed uniformly in a maize leaf. In general, the tips contained appreciably more chromium than the mid-section or the stalk area.

Fruits and seeds are especially low in chromium containing its 20 ppb and cereal grains 40 ppb Cr (Mertz, 1969). Chromium in edible seeds of peas, beans and sweet corn on one site ranged from 10 to 40 ppb (Cary et al., 1977). Buck wheat seed contained only about one-tenth of the chromium in the leaf and stem. There are conflicting views on the uptake of chromic and chromate ions by plant roots. Bourque et al. (1967) working with wheat concluded that chromate but not chromic ions were absorbed by the roots. Myttenaere and Mousny (1974) working with rice have concluded the opposite and they suggested that chromate may be reduced to chromic state before entering the cell. Shewry and Peterson (1974) have indicated that chromate uptake was an active process whereas chromic uptake was passive.

Another study on chromium accumulation by crop plants grown in culture solutions also revealed that the roots of each species supplied with chromic ions contained more chromium than those applied with chromate but the reverse was found in the shoots (Lahouti and Peterson, 1979). They also established that the species differed in their ability to accumulate the element in roots and shoots. Species differences of around 10-fold in the tops and 5-fold in the roots were recorded in cauliflower seedlings, followed by beet root seedlings, accumulating the most chromium while mung-bean

(Phaseolus aureus) and barley seedlings accumulating the least. Cary et al. (1977) have also noted the pronounced difference in chromium accumulation between species when grown in soil or chromium supplemented soil. Beet root plants were again shown to be active accumulators of chromium. Eventhough the tendency to retain chromium in the roots was common to all species, the leafy vegetables with the highest chromium concentrations in their leaves also contained relatively high concentrations of iron.

Chromium may enter sewage treatment works as chromate from the tannery effluents but is apparently reduced to the chromic form (Baetjer, 1974). Sewage sludge from Britain contained 980 ppm chromium (range 40-8800 ppm) (Berrow and Webber, 1972) and from the USA 3400 ppm (range 200-9100 ppm). Regan and Peters (1970) and Furr et al. (1976) reported values upto 14000 ppm Cr (dw). The significance of these high chromium levels compared with the other heavy metals present has not been assessed. De Haan (1978) working in Netherlands, showed that despite high concentrations of chromium in sludge, plant contents were variable. For example, on a sludge containing 1700 ppm chromium, grass contained 67 ppm. While on another sludge containig 1800 ppm chromium the grass contained only 5.6 ppm chromium.

Dowdy and Larson (1975) showed that chromium accumulation by barley seedlings was greater on an acid sludge amended soil than on a calcareous soil.

From the above review, it is evident that rapid urbanization experienced world wide has caused pollution of air, land and water through the vast quantities of wastes generated. Energy crisis, shortage of organic manures and rising prices of fertilizers and soil amendments are among the other problems facing the developing countries today. Under such circumstances, recycling of urban solid wastes as a soil organic matter resource in agriculture can help in meeting a part of the fertilizer requirements. However, before full benefit of this practice is proposed to be derived, it is necessary to evaluate the effect of additions of such wastes on the toxicity or otherwise caused by increased concentrations of heavy metals and other pollutants carried in the urban solid wastes, sludges, sewage and other materials accumulating as wastes.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present investigations were carried out under five different categories as given below :

- 3.1 Characterisation of urban solid wastes, soil and water (ground and surface) at landfill sites
- 3.2 Bioassay for predicting possibility of pollution of soil profiles due to waste disposal at landfill sites
- 3.3 Studies on uptake of micronutrients and heavy metals by maize plant from soil treated with urban solid wastes and farm yard manure
- 3.4 Soil properties, micronutrient and heavy metal concentrations in crop plants and weeds treated with fresh urban solid wastes

3.1 CHARACTERISATION OF URBAN SOLID WASTES, SOIL AND WATER AT LANDFILL SITES

Disposal of urban solid wastes by landfill is the most widely practised method in several Indian cities including Hyderabad. There has been a serious concern about the possible contamination of soils, ground and surface waters when the wastes are, thus, disposed. The methodology employed and material used in

the studies conducted to evaluate the impact of disposal of urban solid wastes generated in Hyderabad as landfill on soil, ground and surface water characteristics are detailed here under :

3.1.1 Landfill sites and urban solid waste sampling methods

3.1.1.1 Landfill sites: In the vicinity of Hyderabad, there are four landfill sites used by the Municipal Corporation of Hyderabad to dispose of urban solid wastes. For the present study, three landfill sites - one within the city (Amberpet) and two others (Golkonda - Plates 1 to 3 and Autonagar - Plates 4 and 5) beyond the city limits were selected.

The details of the landfill sites are given in Table 6.

Table 6 : Details of landfill sites studied at Hyderabad

S.No.	Location of the landfill site	Area (ha)	Approximate quantity of USW recorded (t day ⁻¹)	Landfill age (years)
1.	Amberpet	15	Nil (Dumping of waste was stopped since 1983)	29
2.	Golkonda (Jamalikutta)	10	700-900	20
3.	Autonagar	20	500-600	17



Plate 1 : A view of the Golkonda landfill site - stray pigs salvaging food remnants



Plate 2 : Urban solid wastes being off loaded at the Golkonda landfill site



Plate 3 : Waste components being salvaged at
Golkonda landfill site



Plate 4 : Urban solid wastes composting yard
at Autonagar landfill site



Plate 5 : Urban solid wastes disposed off at
Autonagar landfill site

3.1.1.2 Sampling of urban solid wastes: Urban solid waste is a heterogenous material collected from the Hyderabad city consisting of a number of substances of different origins and characteristics.

Fresh USW grab samples, weighing approximately 10 kg, were collected from ten different locations of Autonagar and Golkonda landfill sites. Similarly, stabilized solid waste samples were also collected from Amberpet and Golkonda landfill sites so as to cover the whole area of the waste dump. The sample of 100 kg of waste thus collected was thoroughly mixed and by quartering technique (NEERI, 1983) the weight of sample was reduced to 12.5 kg. Similarly stabilized solid waste profile sampling was also done at Amberpet (three places) and Golkonda (two places) landfill sites at different depths (0-30, 30-60 and 60-90 cm) from the surface of the dump. The process of quartering was repeated till the weight of sample was approximately 12.5 kg. Besides these material from a waste layer above the surface of the soil was also collected and processed before the soil soil profiles were dug and exposed.

'Fresh solid waste' represents the material disposed off at the landfill site with eight days of the date of collection whereas 'stabilized solid waste' represents the material which was disposed off at the

landfill site atleast 180 days before the date of collection and has undergone decomposition. The stabilized solid waste samples were either collected from depths more than one meter from the surface or from places where wastes has not been dumped for the previous 180 days at the landfill sites.

3.1.2 Analysis of urban solid wastes

3.1.2.1 Physical analysis: The representative samples were sorted out into separate fractions - stone (gravel), plastics, leather, rubber, paper, glass, metals, rags, wood, fine earth and others and weighed. These fractions were then represented as per cent dry weight. From this, the total per cent of compostable matter was calculated. After physical sorting out moisture content was determined from the remaining crude sample as follows :

Moisture: About 500 g of sample was placed in a tray and kept in an electric hot air oven overnight at 100°C . The dried sample was cooled in a dessicator and weighed. Loss in weight of sample (%) was reported as moisture. This estimate was done thrice. (NEERI, 1983).

Weight per cubic meter: The USW was packed in a 1 m^3 box and weighed to determine the density of the USW per unit volume of 1 m^3 . Three separate samples of

USW were, thus, weighed to determine the weight/volume relationship (density).

3.1.2.2 Method for preparation of urban solid waste sample for chemical analysis: The method suggested by the Indian Standards Institution for the preparation of solid wastes for chemical analysis as outlined in their publication IS: 9234-1979, was followed.

The three basic operations required to prepare the sample for detailed analysis are drying, grinding or pulverizing and mixing. The processed materials are thoroughly homogenized and weighed portions were used for analysis. The sample were dried in shade before grinding. After grinding, it was subjected to thorough mixing in a rotary mixer.

3.1.2.3 Chemical analysis of urban solid waste: Standard methods as described by NEERI (1983) and Indian Standards Institution IS: 10158-1982 and other standard methods suggested by recognised agencies were used for chemical analysis of urban solid wastes and farm yard manure.

Details of the chemical methods employed in analysis of organic wastes are given in Table 7.

3.1.3 Collection of water samples

In all, six wells were selected for the studies on ground water characteristics located near the

Table 7: Methods used for chemical analysis of urban solid wastes

S.No.	Test conducted	Out line of the Method	Reference	Remarks
1.	pH	10 g of the sample is placed in a flask and 500 ml distilled water was added and stirred for 3 to 5 minutes. The mixture is settled for 5 minutes and pH is measured using a digital pH meter with a glass electrode after temperature correction.	Indian Standards Institution-10158 (1982)	
2.	Electrical conductivity (EC)	Same sample after determination of pH was used and with the help of digital EC-meter the EC was measured.	Stewart and meek (1977)	
3.	Organic carbon (O.C.)	Chromic acid wet digestion method (Walkey and Black) without the correction for total recovery. Where 0.5 g of waste sample is placed in the flask and 20 ml of 1 N K ₂ Cr ₂ O ₇ is added. Then 40 ml of H ₂ SO ₄ is added +200 ml Distilled water. Diphenyl amine indicator is used and titrated with Ferrous ammonium sulphate solution (0.5 N).	Jackson (1965)	
4.	Organic matter O.M. = % organic carbon x 1.724		-do-	
5.	Chemical oxygen demand (C.O.D.)	Chromic acid wet digestion method as in O.C. determination. $\text{C.O.D. mg g}^{-1} = \frac{(\text{Blank T.V. ml} - \text{sample T.V. ml}) \times N \text{ of ferrous ammonium sulphate Xeq. Wt of O}_2}{\text{Sample wt (mg)}} \times 1000$	Lossin (1971)	

(Contd...)

S.No.	Test conducted	Out line of the Method	Reference	Remarks
6.	Volatile organic matter	About 5 g of finely ground sample was placed in a constant mass silica dish and heated in an electric furnace upto a temperature of 600°C and for 2 hours. The dish was cooled in a dessicator and wt. was taken. This was done in triplicate.	Indian Standards Institution: 10158- (1982)	
		Volatile substance = $\frac{\text{Initial mass} - \text{Final mass}}{\text{Initial mass}} \times 100$		
7.	Total Nitrogen	5 g sample digested and distilled with NaOH 40 per cent and tritrating distillate with 0.1 M H ₂ SO ₄ using mixed indicator	-do-	
8.	Total Phosphorus	1.0 g sample + 5 ml of H ₂ SO ₄ + 5 ml of HNO ₃ and heated. 10 ml H ₂ O added and heated and digested in HF. Vol. is made to 250 ml. This aliquot is used for analysis formation of phosphomolybdic acid in a solution free from ammonium salts, followed by its precipitation as the salt of quinoline. Finally the quinoline phosphomolybdate is titrated with sodium hydroxide.	-do-	
9.	Total Potassium	1.0 g sample is decomposed by 5 ml H ₂ SO ₄ + 5 ml HNO ₃ mixture and 10 ml HF. Sample aliquot is then subjected to flame photometric analysis.	-do-	
10.	Total Calcium Magnesium and Sodium	1.0 g sample is weighed and 10 ml HNO ₃ + 3 ml HClO ₄ (50%) added and heated on hot plate. Cooled and added 10 ml HCl (1+1) and quant is transferred to 50 ml Vol. Flask. Ca and Mg are determined by EDTA Method and Na by Flame Photometer after suitable dilution.	AOAC (1980)	

(Contd...)

(Contd... Taable 7)

S.No.	Test conducted	Out line of the Method	Reference	Remarks
11.	Total Iron, Copper,Manganese and Zinc	--do-- (Atomic absorption spectro photometer was used for micronutrient analysis)	-do-	
12.	Total Lead, Nickel, Cadmium, Chromium and Cobalt	--do--	-do-	5 g sample is weighed and 40 ml HNO3 +12 ml HClO4 (60%) is added and quant, analysed for metals
13.	Water soluble:	Saturation extracts were prepared and aliquot is used for analysis.	-do-	
	Sulphate Chloride Sodium and Potassium	-Sulphate - estimated by BaCl ₂ procedure -Chloride - estimated by AgNO ₃ and K ₂ CrO ₄ procedure -Sodium and Potassium - estimated by Flame photometer after proper dilution.		
14.	Cation exchange capacity (CEC)	2.00 g sample is shaken with 0.5 N HCl, Excess acid is removed, absorbed H ⁺ is replaced with Ba ²⁺ (0.5 N Ba(OAc) ₂ titrated with 0.1 N NaOH, using Phthln indicator CEC = (ml x normality of NaOH x 100) / g sample (Cmol (p ⁺) kg ⁻¹ waste)	-do-	

(Contd...)

S.No.	Test conducted	Out line of the Method	Reference	Remarks
15.	DTPA - extrac- table trace metals (Fe, Mn, Zn, Cu, Pb, Ni, Co, Cr and Cd)	1.0 g waste + 20 ml DTPA + shaking for 2 hours and filtered and estimated by Atomic absorption spectro photometer. Diethylene-triamine penta acetic acid + CaCl_2 + Triethanol amine ~ with pH adjusted to 7.3 ± 0.05 with dil. HCl.	Lindsay and Norvell (1978)	
16.	Calcium Carbonate (CaCO_3)	5.0 g of waste transferred to a tall 150 ml beaker and 100 ml of N HCl was added and covered and stirred vigorously for one hour. Then 20 ml of liquid was pipetted out to a flask and 6-8 drops of Bromothymol Blue indicator was added and titrated with N NaOH.	Piper (1950)	
17.	Exchangeable Ca, and Mg	Extracted with sodium acetate method and aliquot was titrated with versenate solution.	Bower et al. (1952)	
18.	Exchangeable K and Na	Obtained by deducting water soluble K and Na from the N ammonium acetate extractable K and Na.	Page (1982)	
19.	Available Nitrogen	10.0 g sample was taken in Kjeldahl flask, digested and distilled in presence of catalyst and distillate is collected in H_2SO_4 + methyired indicator sol. and titrated against NaOH	Indian Standards Institution-10158 (1982)	
20.	Available Phosphorus	Olsens extract was used and estimated by ascorbic acid method.	Olsen et al. (1954)	

(Contd...)

(Contd... Taable 7)

S.No.	Test conducted	Out line of the Method	Reference	Remarks
21.	Available Potassium	Extracted with neutral N NH ₄ OAc with waste : extract ratio at 1 : 5 and shaking for 5 minutes and estimated by a flame photometer after proper dilution.	Hanway and Heidal (1952)	
22.	NH ₄ OAc extractable sodium	---	Bower et al. (1952)	
23.	Relative availability of Metals (%)	Concentration of DTPA-extractable metal Concentration of Total - extractable metal ----- x 100	Williams et al. (1980)	
24.	Cd/Zn (%)	Total Cd concentration Total Zn concentration ----- x 100	Chaney (1973)	

landfill sites. They were selected at different distances from the fringe of landfill sites. Details of the wells chosen for obtaining water samples at Amberpet and Golkonda landfill sites are given in Table 8.

Water from the first five wells was used for all domestic purpose except drinking while water from well No.6 (Borewell) is also used for drinking purpose by inhabitants of the area.

Ground-water samples were collected during rainy season (July, 1987) and summer season (May, 1990) from Amberpet landfill site, whereas samples from Golkonda landfill site were collected during summer (May, 1990) only.

Surface runoff water samples were also collected from Amberpet landfill site during rainy season (July, 1987).

3.1.3.1 Method of collection of Ground-water samples: Water samples were collected from two landfill sites of Hyderabad city (Fig.1 and Plate 6). Information pertaining to the wells was collected from the land owners where the wells are located or by interviewing the residents living in the vicinity through a questionnaire developed for this purpose (Table 8).

Stoppered polyethylene bottles of two litre capacity were used for collecting water samples. Each

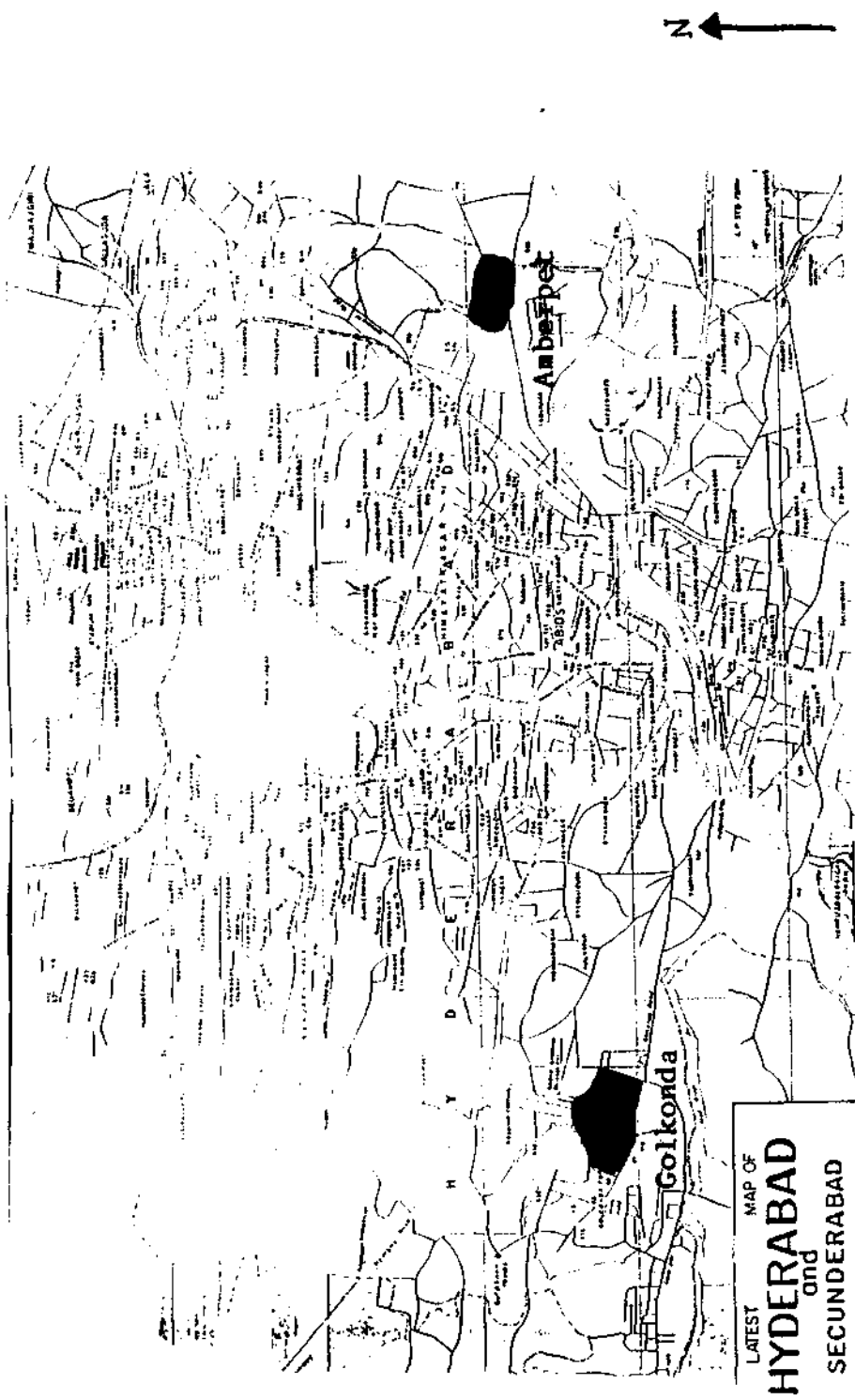


Fig. 1 Map showing part of Hyderabad city where Golkonda and Amberpet landfill sites are located



Plate 6 : A view of an open well (Well No.1)
at Amberpet landfill site

Table 8 : Details of wells at landfill sites

Amberpet					Golkonda				
Well No.	Distance from land-fill site (m)	Age of the well (upto 1987) in years	Depth of Sampling well (m)	Diameter of the well (m)	Distance from land-fill site (m)	Age of the well (upto 1987) (in years)	Depth of Sampling well (m)	Diameter of the well (m)	
1	65.0	25 - 26	2	15 (open)	5.0	40.0 (lake)	1.0	0.5 acre	
2	80.0	6 - 8	3	1.5 (open)	50.0	10 - 12	0.5	4.0 (open)	
3	100.0	4 - 6	1.5	1.5 (open)	90.0	10 - 11	1.0	3.0 (open)	
4	200.0	3.6-4.0	2.0	2.0 (open)	150.0	15 - 17	1.0	4.0 (open)	
5	300.0	2.0-3.0	6.0	1.5 (open)	175.0	10 - 12	1.0	5.0 (open)	
6	350.0	2 months	35	4" 0 (bore well)	300.0	10 - 12	50.0	4" 0 (bore well)	

bottle was washed with dilute HCl and then rinsed with distilled water. A clean water sampler was introduced into the well with the help of rope and water was taken out. Prior to sampling, the bottle was rinsed thoroughly with the water of the source from which the sample was drawn. Necessary information was filled in the proforma. The water temperature was measured in situ. Dissolved oxygen, pH and EC were measured immediately and samples were stored at 4°C until use, for physico-chemical analysis. Sterilized glass bottles were used for collecting water samples for bacteriological (coliforms) analysis. Details of the methods used in water analysis is given in Table 9.

For metal analysis, separate glass bottles were used for sampling. Water samples were acidified with 1.5 ml $\text{HNO}_3 \text{ L}^{-1}$ (APHA, 1985). Standard methods (APHA, 1985) were followed for determining the physico-chemical and chemical characteristics of waters. Necessary precautions were taken in collection and preservation of water samples for chemical and bacteriological analyses.

3.1.4 Collection of soil profile samples from landfill site:

To study the impact of long term disposal of urban solid wastes on soil characteristics, four soil profiles (1 to 4) from the Amberpet landfill site were

Table 9 : Methods used for water analysis

S.No.	Test conducted	Unit	Principle of the method	Reference
1	Temperature	$^{\circ}\text{C}$	Precision thermometer, measured in situ	American Public Health Association, 1985. Standard Methods for the examination of water and waste water. American Public Health Association, Washington, D.C., U.S.A.
2	Electrical conductivity	d S m^{-1}	Digital conductivity bridge	-do-
3	Turbidity	NTU	Turbidimeter	-do-
4	Total solids	mg l^{-1}	Evaporation	-do-
5	Total dissolved and suspended solids	mg l^{-1}	Filtration and evaporation	-do-
6	pH	--	Digital pH meter	-do-
7.	Chemical oxygen demand (COD)	mg l^{-1}	Org. sub. are oxidized by $\text{K}_2\text{Cr}_2\text{O}_7$ in H_2SO_4 (1+1) at reflux temperature	-do-
8	Total alkalinity as CaCO_3	mg l^{-1}	Titration with std. H_2SO_4 P-Alkalinity + MO- Alkalinity ----- x 100 ml sample	-do-
9	P-Alkalinity as CaCO_3	mg l^{-1}	$A \times 1000$ ----- ml sample A=Vol. of H_2SO_4 required in presence of phenolphthalein	-do-
10	MO-Alkalinity as CaCO_3	mg l^{-1}	$B \times 1000$ ----- ml sample B = vol. of H_2SO_4 required in presence of methyl orange	-do-

Contd...

(Contd...Table 9)

S.No.	Test conducted	Unit	Principle of the method	Reference
11	CO_3	mg l^{-1}	When $P < 1/2 T$ $T = 2P$ $P = 1/2 T = 2P$ $P = T = 0$	-do-
12	HCO_3	mg l^{-1}	When $P < 1/2 T$ $T = T-2P$ $P = 1/2 T = 0$ $P = T = 0$	-do-
13	Chloride	mg l^{-1}	Titration with stand. AgNO_3 using $\text{K}_2\text{Cr}_2\text{O}_7$ as Indicator	-do-
14	Total hardness	mg l^{-1}	EDTA-titrimetric method	-do-
15	Ca hardness as CaCO_3	mg l^{-1}	$C \times D \times 1000$ = ----- ml sample Where C = Vol. EDTA D = mg CaCO_3 per 1.0 ml EDTA used for titration	-do-
16	Mg. hardness as CaCO_3	mg l^{-1}	= Total hardness - Ca hardness as CaCO_3 as CaCO_3	-do-
17	Carbonate hardness	mg l^{-1}	= When total > total alkalinity hardness Then Alkaline = Total Alkalinity hardness When TH < TA Then Alkaline = Total hardness hardness	-do-
18	Non-alkaline hardness	mg l^{-1}	If TH > TA = Total hardness - Total Alkalinity If TH < TA non-alkalinity hardness = Nil	-do-

Contd...

(Contd...Table 9)

S.No.	Test conducted	Unit	Principle of the method	Reference
19	Sulphate	mg l ⁻¹	Turbidimetric using BaCl ₂	-do-
20	Fluoride	mg l ⁻¹	Zirconium 'SPADMS' solution	-do-
21	Nitrate-N (NO ₃)	mg l ⁻¹	Phenol disulphonic acid	-do-
22	Ammonia-N (NH ₄)	mg l ⁻¹	Acidimetric using Std. H ₂ SO ₄ using mixed indicator	-do-
23	Dissolved oxygen	mg l ⁻¹	Dissolved oxygen analyser (Gold platinum electrode)	-do-
24	Sodium and potassium	mg l ⁻¹	Flame Photometer	-do-
25	Metals (Fe, Zn, Cu, Mn, Pb, Ni Cr, Co and Cd)	ug l ⁻¹	Atomic absorption spectro photometer	-do-
26	B.O.D.	mg l ⁻¹	Sample measured at 5 days at 20°C	-do-
27	PO ₄ -P	mg l ⁻¹	Colorimetric analysis using ascorbic acid method	-do-
28	Boron	mg l ⁻¹	Curcumin	-do-
29	Coliforms	MPN/100 ml	Multiple-tube fermentation technique	-do-
30	Dissolved CO ₂	mg l ⁻¹	Titrimetric using phenolphthalein as indicator	-do-

Table 10 : Methods used for soil analysis

S.No.	Test conducted	Method	Reference
1	Particle size analysis	Hydrometer	Piper (1950)
2	pH and EC	Soil water suspension (1:2)	Jackson (1973)
3	Organic Carbon	Chromic acid wet digestion (Walkey and Black)	Jackson (1973)
4	Calcium Carbonate	Rapid titration	Chapman and Pratt (1961)
5	NH ₄ OAc extractable Na and K	In 1 N NH ₄ OAc leachate-using flame photometer	Jackson (1973)
6	Exchangeable Ca and Mg	Sodium acetate method	Bower <u>et al.</u> (1952)
7	Exchangeable Na and K	Obtained by deducting the water soluble Na and K from 1N NH ₄ OAc extractable Na and K	Page (1982)
8	Available Nitrogen	Alkaline Permanganate	Subbaiah and Asija (1956)
9	Total nitrogen	Modified Kjeldahl	Jackson (1973)
10	Available Phosphorus	Olsen's extractant (sodium bicarbonate)	Olsen <u>et al.</u> (1954)

Contd...

(Contd...Table 10)

S.No.	Test conducted	Method	Reference
11	Cation exchange capacity (CEC)	Sodium acetate method, of Bower <u>et al.</u> (1952)	Richards <u>et al.</u> (1954)
12	DTPA-extractable metals (Zn, Fe, Cu, Mn, Pb, Ni, Cr, Cd and Co)	DTPA + CaCl ₂ + TEA with pH adjusted to 7.3 + 0.05 with dil.HCl	Lindsay and Norvell (1978)
13	Total metals (Zn, Mn, Cu, Fe)- (Cr, Cd, Pb, Ni, and Co)	HN03 + HClO ₄ 0.5 g soil + HN03 + HClO ₄ (1:2) - 2.0 g soil + HN03+HClO ₄ (1:2) Final Vol. made to 50 ml	Sandell and Onishi (1978)
14	Water soluble: Na and K Sulphate Chloride	Saturation extracts - Flame photometer - BaCl ₂ method - Ag NO ₃ and K ₂ Cr ₂ O ₇ method	Richards (1954)
15	E.S.P.	Exchangeable Na ⁺ (Cmol(P ⁺) kg ⁻¹ soil) ----- x 100 C.E.C. (Cmol (P ⁺) kg ⁻¹ soil)	Soil Science Society of America (1984)
16	Cd/Zn (percentage)	Total Cd concentration ----- x 100 Total Zn concentration	Chaney (1973)
17	Relative availability of metals (%)	Concentration of DTPA extractable metal ----- x 100 Concentration of total metal	--

selected. For this purpose, the solid wastes covering the land surface were cleared to expose the surface soil before the profile pits were dug. In addition, two soil profiles (A and B) were selected at 10 and 100 m away from the fringe of the landfill site, the soils of which were influenced by periodical stagnation of runoff water flowing from the landfill site. A profile from higher elevation where the soil is neither affected by waste disposal nor runoff water flowing from the landfill site was also selected from the adjacent area, where the landfill site is located. This profile served as the experimental control as it was unaffected by solid waste disposal. Each profile pit was dug up to a depth of 2.10 m and soil samples were drawn at intervals of 30 cm.

The soil samples collected were dried in shade pounded using a wooden pestle and mortar and passed through a 2 mm sieve. The methods used for chemical analysis of soils are given in Table 10.

3.2 BIOASSAY FOR PREDICTING POSSIBILITY OF POLLUTION OF SOIL PROFILES DUE TO WASTE DISPOSAL AT LANDFILL SITES

For this study, soil profile samples collected as mentioned in Section 3.1.4 were used. A total of seven soil profiles were studied including control.

For the bioassay, one hundred gram portions of the soils from each depth were weighed in glass dishes. (15 cm in diameter and 6 cm in height) in triplicate. Uniform sized seeds of Italian millet (Setaria italica L.) at the rate of 100 seeds were sown in each dish. The dishes were incubated in a light chamber and the seedlings were grown for 15 days. As and when required, the dishes were watered using double distilled water to make up the loss of water which was determined by weighing of each dish. After 15 days of sowing, the plants were uprooted, washed with double distilled water and the shoots were dried for 72 hours at 65° C and weighed to determine the dry matter yield.

3.2.1 Effect on germination

Before taking up Italian millet as a test crop for bioassay, several other field crops were tested. Soil samples collected from 0-30 to 180-210 cm depths of soil profile No.4 were used for the germination and growth test. The soil samples of this profile were specifically chosen because of the wide range of EC of 2.87 to 10.86 d S m⁻¹ recorded among the different depths, thus facilitating screening for salinity tolerance. It was observed that the germination of the following crops was poor on all the soils tested. Besides this, the growth of seedlings was also affected.

Cereals and millets	<u>wheat</u> , <u>maize</u> , <u>jowar</u> , <u>bajra</u> and <u>ragi</u>
Pulses	<u>redgram</u> and <u>greengram</u>
Oilseeds	<u>groundnut</u> , <u>sesamum</u> , <u>sunflower</u> and <u>mustard</u>
Vegetables	<u>tomato</u> , <u>brinjal</u> , <u>bhendi</u> and <u>spinach</u>
Spices and condiments	<u>chillies</u> and <u>coriander</u>

As the above crops failed to grow well except Italian millet it was chosed for the bioassay study.

3.3 STUDIES ON UPTAKE OF MICRONUTRIENTS AND HEAVY METALS BY MAIZE FROM SOIL TREATED WITH URBAN SOLID WASTES AND FARM YARD MANURE

A pot culture experiment was conducted to study the uptake of micronutrient and heavy metals by maize grown on soils treated with urban solid wastes. In this study four sources of organic wastes were used for purpose of comparison. The wastes used were:

- a) Stabilized urban solid wastes from Amberpet landfill site
- b) Stabilized urban solid wastes from Golkonda landfill site
- c) Fresh urban solid wastes from Golkonda landfill site
- d) Farmyard manure collected from cattle shed

The characteristics of soil FYM and organic solid wastes used in the study are provided in Tables 11, 12 and 17, respectively.

Surface soil upto a depth of 15 cm was collected from the uncultivated fields of Students' Farm, College of Agriculture, Rajendranagar, air dried in shade and were pounded to pass through a 2 mm sieve.

The organic wastes collected from the locations as mentioned were dried in shade, pounded to pass through a 2 mm sieve after physical separation of non-degradable materials.

The soil was filled in at the rate of 5 kg in earthen pots of size 20 cm in diameter and 40 cm in height. A basal application of N, P_2O_5 and K_2O at 60, 60 and 50 kg ha⁻¹ was done as urea, single super phosphate and muriate of potash, respectively. Organic wastes were applied to soil at 5 levels viz., 0, 11, 22, 33 and 44 t ha⁻¹. The contents of pots were mixed thoroughly to ensure uniform distribution of wastes and fertilizers in soil of pots. The pots were irrigated and kept for two days for equilibration before sowing the maize crop. Four maize seeds (Cv. DHM 103) were initially sown in each pot, and the seedlings germinated were thinned after seven days to have only two per pot. Each treatment was replicated four times (Plate 7).

The moisture status of soil in pots was maintained by irrigating whenever necessary with deionised water.



Plate 7 : A view of the pot culture experiment conducted to evaluate urban solid wastes as a manure with maize as test crop

Table 11 : Characteristics of soil used in pot culture experiment

Characteristics	
1. Physical	
a) texture	Loamy sand
b) sand (%)	83.0
c) silt (%)	8.0
d) clay (%)	9.0
2. Physico-chemical and chemical	
a) pH (1:2)	6.1
b) EC ($d S m^{-1}$)	0.03
c) Organic carbon (%)	0.60
d) $CaCO_3$ free (%)	1.00
e) Exchangeable cations ($Cmol (P^+) kg^{-1}$ soil)	
i) Ca^{2+}	2.0
ii) Mg^{2+}	1.0
iii) K^+	0.11
iv) Na^+	0.02
f) Available major nutrients (ppm)	
i) nitrogen	73.00
ii) phosphorus	8.00
iii) potassium	65.00
Contd...	

(Contd...Table 11)

=====

Characteristics

g) Cation exchange capacity 3.90
(Cmol (P⁺) kg⁻¹ soil)

h) DTPA-extractable micronutrients
and heavy metals (ppm)

i) Fe	8.07
ii) Zn	1.09
iii) Mn	11.09
iv) Cu	0.92
v) Pb	0.15
vi) Ni	0.08
vii) Co	0.05
viii) Cr	ND
ix) Cd	ND

i) Total concentration of (HNO₃ + HClO₄)
micronutrients and heavy metals (ppm)

i) Fe	2840.00
ii) Zn	8.20
iii) Mn	180.00
iv) Cu	1.30
v) Pb	6.10
vi) Ni	2.60
vii) Co	3.00
viii) Cr	15.40
ix) Cd	1.00

=====

ND - Not detected

Table 12 : Chemical characteristics of farm yard manure (FYM) used in the pot culture experiment

Characters	pH	EC μSm^{-1}	organic carbon (%)	organic matter (%)	C.O.D. (mg g^{-1})	C.E.C. $(\text{Cmql(P+) kg}^{-1})$	CaCO ₃ free (%)	C/N ratio
	8.64	665	10.80	18.60	288.00	185.00	ND	7.10

Total (%)															
Characters	N	P	K	Ca	Mg	Na	Fe	Zn	Cu	Mn	Pb	Ni	Co	Cr	Cd
	1.52	0.87	1.64	0.46	0.065	0.032	3130.00	43.00	7.00	34.00	2.00	3.00	2.00	3.00	0.01

DTPA-Extractable (ppm)										Cd/Zn Water soluble ions (ppm)				
Characters	Fe	Zn	Cu	Mn	Pb	Ni	Co	Cr	Cd	ratio				
	7.00	6.80	0.90	18.00	0.20	0.30	0.10	ND	ND	0.023	11456.00	285.00	200.00	210.00

Characters	Fe	Zn	Cu	Mn	Pb	Ni	Co	Cr	Cd	K ⁺	Na ⁺	SO ₄ ²⁻	Cl ⁻

ND = Not detected

At the flag leaf stage of maize i.e., at 40 days after sowing, urea was top-dressed at the rate of 60 kg N ha⁻¹ uniformly to all the pots.

The maize plants were harvested at 70 DAS, washed and dried at 65°C and dry matter yields were recorded. Root samples were also collected along with soil samples after harvest of the crop. The plant (root, shoot and leaf) and soil samples were processed separately and analysed for contents of micronutrients and heavy metals. The methods used for analysis of soil samples before and after harvest of the maize plant are detailed in Table 10. The methods used for analysis of plant samples are described under section 3.3.2.

3.3.1 Analysis of soils

Soil samples were collected, air dried, powdered and sieved using a 2 mm sieve and used for analysis. The methods employed for soil analysis are detailed in Table 10.

3.3.2 Plant analysis

To determine the micronutrients and heavy metals in different plant parts, 1.0 g of the plant part was digested with 10 ml of concentrated HNO₃ and 3 ml HClO₄ for 3 hours (AOAC, 1980). The residue dissolved in 5 ml of 6 N HCl was made upto 50 ml with double

distilled water. The extracts were assayed for metals by using an atomic absorption spectrophotometry (Varian model-AA 20).

3.4 SOIL PROPERTIES, MICRONUTRIENT AND HEAVY METAL CONCENTRATION IN CROP PLANTS AND WEEDS TREATED WITH FRESH URBAN SOLID WASTES

It is a very common practice in and around Hyderabad, as is in other parts adjoining urban centres in India to use fresh urban solid wastes (FUSW) as a manure and soil conditioner for the cultivation of crops (Plates 8 to 17). Previous report of Purvis and Mckenzie (1973) has highlighted the fact that land application of fresh urban solid wastes may increase the concentrations of microelements and heavy metals in soils as well as in plants cultivated in such soils. To evaluate the status of heavy metal and micronutrients in soils and plants, different locations in the vicinity of Hyderabad where fresh urban solid wastes are being used regularly for the past 10 years or more were selected. The details of the sampling sites are given in Table 13. The soil and plant samples for this study were collected in the following manner.

3.4.1 Soils

Soil samples were collected from two depths i.e., 0-15 and 15-30 cm from the selected farmers'



Plate 8 : Use of urban solid wastes for cultivating a vegetable crop (radish)



Plate 9 : Fresh stored before crops urban solid wastes being for application to land cultivation of vegetable



Plate 10



Plate 11

Plate 10 & 11 : Use of urban solid wastes for paddy cultivation



Plate 12 : Stocking of fresh urban solid wastes for application to land



Plate 13 : Cultivation of sorghum using urban solid wastes as manure



Plate 14 : Cultivation of Hibiscus sp. using
fresh urban solid wastes as manure

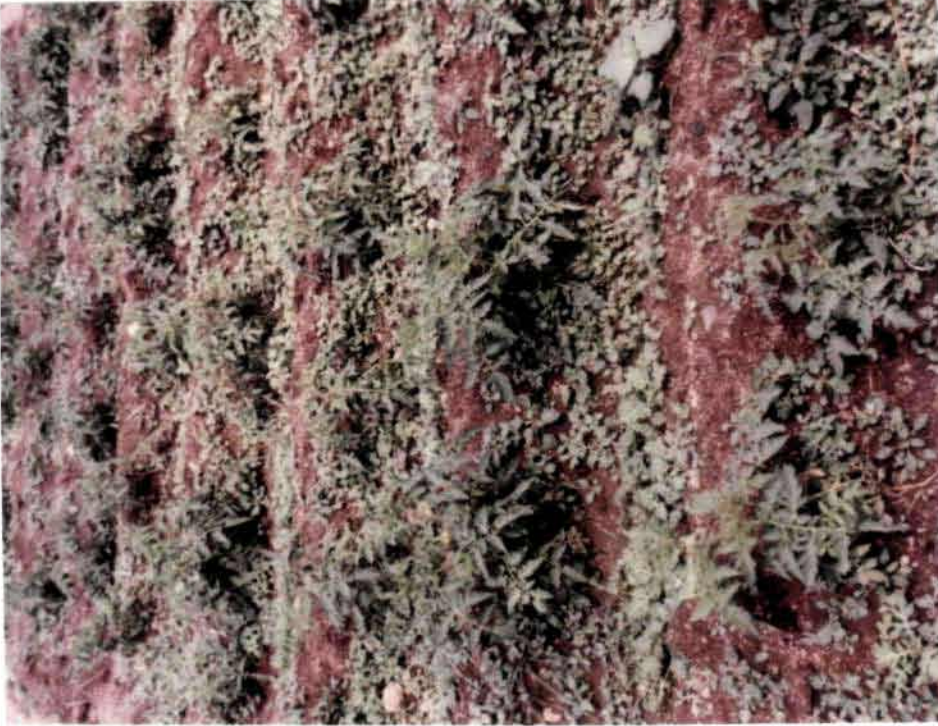


Plate 15 : Cultivation of tomato using
urban solid wastes as manure fresh

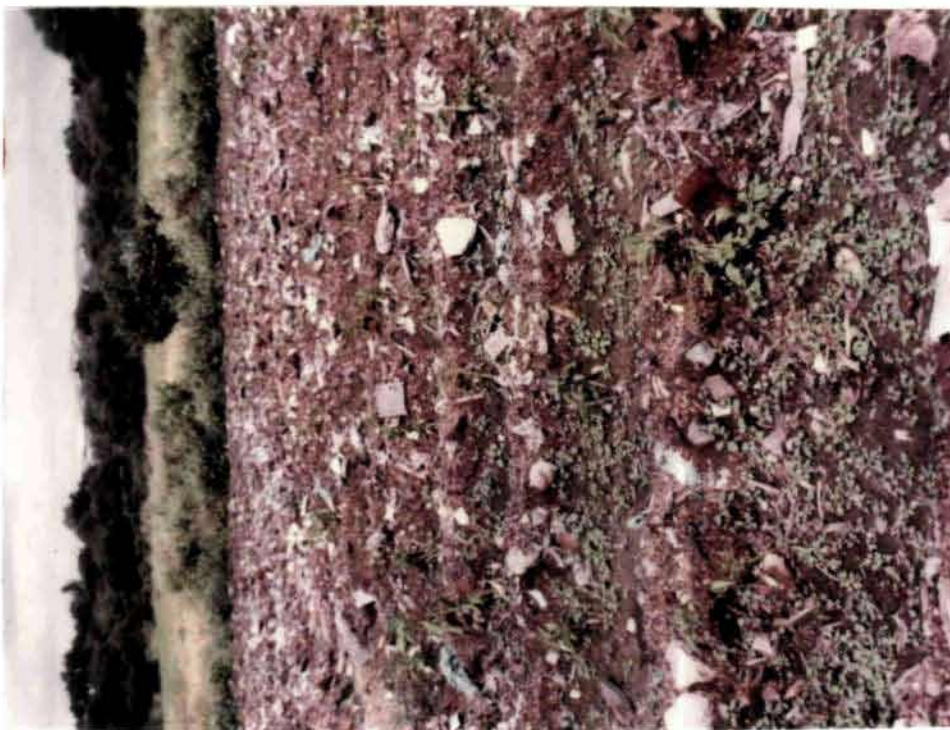


Plate 16 : A view of the field treated with fresh urban solid wastes for cultivating chilli

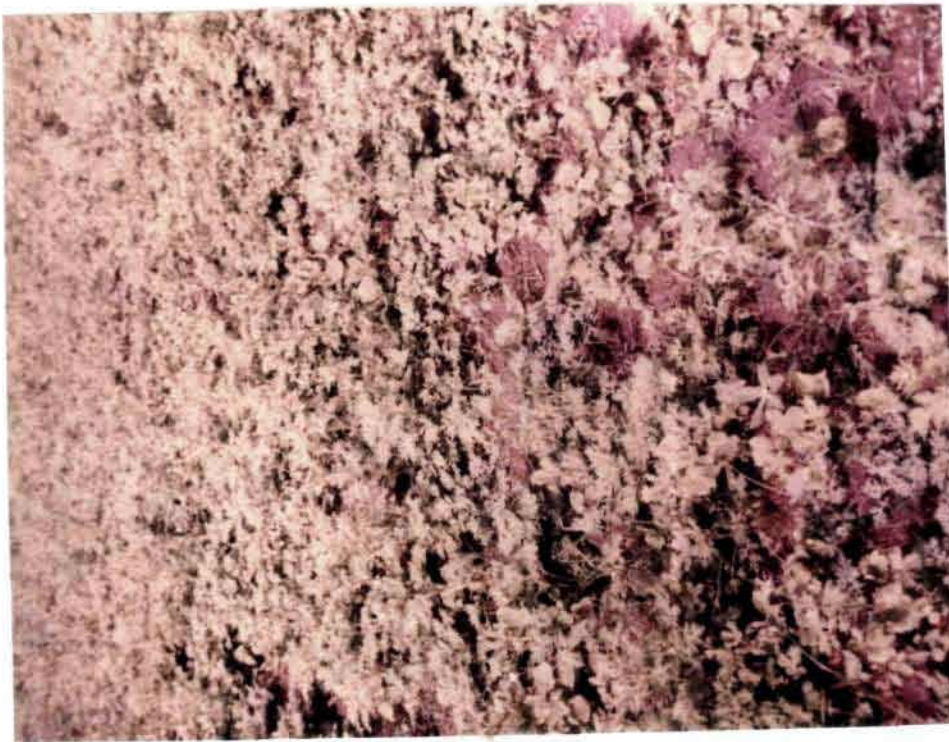


Plate 17 : Weed infestation in bhendi crop due to use of fresh urban solid wastes

**Table 13 : Studies on impact of land application of fresh urban solid wastes on soil properties and plant uptake of micronutrients and heavy metals
- Details of the sampling sites**

Site	Village	District	Area (ha)	No. of years waste applied	Approximate quantity of USW applied
1	Hyderguda	R.R.Dist.	1.0	> 10	90-100 t ha ⁻¹ every year
2	Upperpalli	do.	1.2	> 10	80-90 t ha ⁻¹ every year
3	Upperpalli	do.	2.0	> 10	90-100 t ha ⁻¹ every 2 years
4	Hyderguda	do.	0.5	> 10	90-100 t ha ⁻¹ every year
5	Hyderguda	do.	1.5	> 10	90-100 t ha ⁻¹ every 2 years
6	Golkonda (Banjari- Dharwaja)	do.	1.0	> 20	110-120 t ha ⁻¹ every 3-4 years.
7	Golkonda (Banjari Dharwaja)	do.	1.0	> 20	110-120 t ha ⁻¹ every 3-4 years
8	Hyderguda (control)	do.	uncultivated land	Nil	Nil

Table 14 : Studies on impact of land application of fresh urban solid wastes on soil properties and plant uptake of micronutrients and heavy metals - details of the soil and plant samples collected

Site	Plants collected	Age of the plant	Plant parts collected	Cultivar
1	Paddy (<u>Oryza sativa</u>)	at harvest	Straw+Seed	Bapatla masoori
2	Chillies (<u>Capsicum annum</u>)	30 DAS	Root+Shoot+Fruit	G-3
	Jowar (<u>Sorghum bicolor</u>)	60 DAS	Root+Shoot	CSH-5
3	Bottlegourd (<u>Lagenaria siceraria</u>)	30 DAS	Root+Shoot	Arka bahar
	Parthenium	60 DAS	Root+Shoot	--
	Shendi (<u>Abelmoschus esculentus</u>)	60 DAS	Root+Shoot+Fruit	Pusa sawani
	Hibiscus sp.	60 DAS	Root+Shoot	--
4	Beetroot (<u>Beta vulgaris</u>)	At harvest	Tuber+Shoot	local
5	Radish (<u>Raphanus sativus</u>)	38 DAS	Tuber+Shoot	local
6	Chillies	30 DAS	Root+Shoot	G-3
	Tomato (<u>Lycopersicon esculentum</u>)	15 DAS	Root+Shoot	Pusa early dwarf
	Brinjal (<u>Solanum melongena</u>)	15 DAS	Root+Shoot	Pusa purple long
7	Jowar	At harvest	Root+Shoot+Seed	local
8	Nil (control)	Nil	Nil	Uncultivated land

DAS - Days after sowing

fields and from different plots where food vegetable crops were grown. Soil samples were also collected from plots not treated with urban solid wastes (control) in the vicinity of plots where urban solid wastes are being applied for crop production.

3.4.2 Plants

Food crops representing different types of vegetables, grain cereals etc., and parthenium weed which is dominant in such soils were collected from various farmers' fields. The details of the plant samples collected are given in Table 14.

Dry matter yields of different plant species were recorded and samples were drawn for analyses of micronutrients and heavy metals.

3.5 STATISTICAL ANALYSIS

Statistical methods recommended by Gomez and Gomez (1984) were employed to process the data generated from laboratory, greenhouse and field studies. The data on various characters were computerised and subjected to the statistical analysis.

RESULTS

CHAPTER IV

RESULTS

The results of investigations carried out in the present study are presented in this chapter.

4.1 PROPERTIES OF URBAN SOLID WASTES

The physical, physico-chemical and chemical properties of the urban solid waste samples are presented below.

4.1.1 Physical composition

4.1.1.1 Fresh urban solid wastes: Data are presented in Table 15. A comparison between the mean values of Autonagar and Golkonda fresh solid wastes revealed the following results.

The Autonagar fresh solid wastes contained more non-compostable materials than in Golkonda samples (Fig.2).

The gravel content in various fresh samples of Autonagar ranged from 4.5 to 22.0 per cent with a mean of 12.5. Whereas in Golkonda samples, it ranged from 3.2 to 11.4 per cent with a mean of 6.2.

The glass content varied from 0.1 to 2.0 per cent with a mean of 1.0 in Autonagar samples whereas in Golkonda samples, it varied from 0.08 to 0.8 per cent with a mean of 0.5.

The rags (cotton and cloth wastes) content varied from 0.8 to 8.0 per cent with a mean of 7.0 in Autonagar samples, whereas in Golkonda samples it varied from 1.0 to 3.5 per cent with a mean of 2.1.

The paper content varied from 0.7 to 4.7 per cent with a mean of 2.0 in Autonagar samples whereas in Golkonda samples, it ranged from 0.9 to 2.4 per cent with a mean of 2.0.

The metals in the urban solid wastes ranged from 0.02 to 2.2 per cent with a mean of 1.0 in Autonagar samples whereas in Golkonda samples, it ranged from 0.05 to 2.6 per cent with a mean of 1.3.

The leather and rubber component ranged from 0.4 to 4.2 per cent with a mean of 2.1 in Autonagar samples. In Golkonda samples, it ranged from 0.2 to 2.1 per cent with a mean of 1.6.

The plastics fraction in the urban solid wastes ranged from 0.05 to 3.4 per cent with a mean of 1.0 in Autonagar samples, whereas in Golkonda samples, it ranged from 0.5 to 2.5 per cent with a mean of 1.4. The earth and ash content of Autonagar samples ranged from 32.0 to 64.0 per cent with a mean of 35.0 whereas in Golkonda samples it ranged from 10.2 to 24.0 per cent with a mean of 20.5.

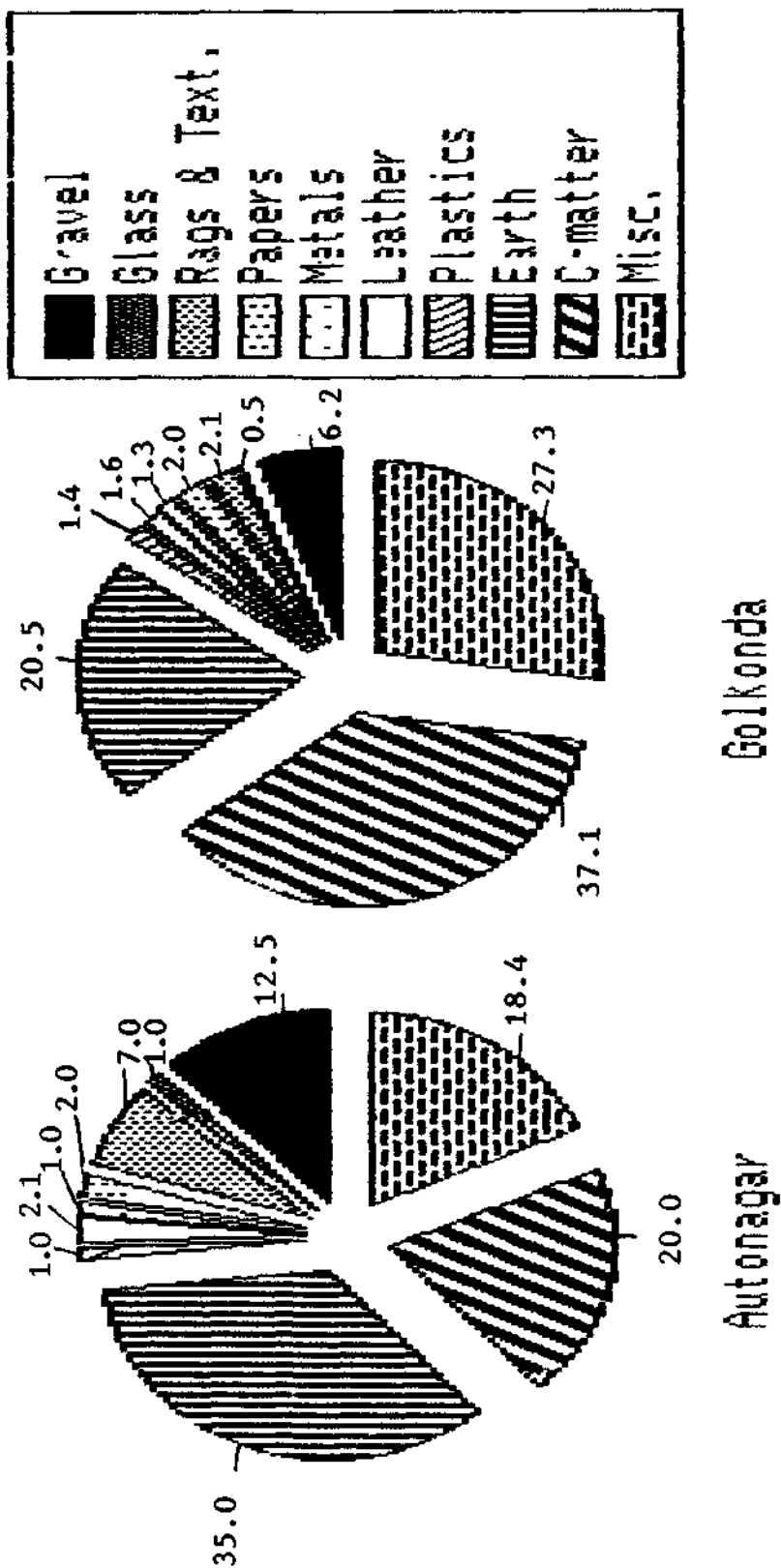


Fig. 2 Histogram showing the composition of fresh urban solid wastes (%) from two landfill sites

The compostable matter of Autonagar samples ranged from 16.2 to 33.0 per cent with a mean of 20.0 whereas in Golkonda samples, it ranged from 20.3 to 47.5 per cent with a mean of 37.1.

The miscellaneous material content ranged from 18.0 to 22.0 per cent with a mean of 18.4 in Autonagar samples whereas in Golkonda samples, it ranged from 22.0 to 35.0 per cent with a mean of 27.3.

The moisture content ranged from 16.0 to 35.0 per cent with a mean of 27.0 in Autonagar wastes. In Golkonda waste samples it ranged from 25.0 to 45.0 per cent with a mean of 38.0.

The density of wastes ranged from 210 to 536 kg cu m³ with a mean of 410 for Autonagar and for Golkonda samples it ranged from 305 to 412 kg m³ with a mean of 365.0.

4.1.1.2 Stabilized urban solid wastes: The data are presented in Table 15. The content of non-volatile matter was more in Amberpet samples than in Golkonda samples (Fig.3).

The gravel content ranged from 19.0 to 28.0 per cent with a mean of 20.0 for Amberpet samples whereas it ranged from 9.0 to 19.0 per cent with a mean of 15.0 for Golkonda samples.

The glass content varied from 0.4 to 1.3 per cent in Golkonda samples with a mean of 1.10, whereas it ranged from 0.7 - 1.6 per cent in Amberpet samples with a mean of 1.0.

The rags content ranged from 0.4 to 1.1 per cent in Golkonda samples with a mean of 0.7 whereas it varied from 0.8 to 1.4 per cent in Amberpet samples with a mean of 1.0.

The paper content ranged from 0.6 to 1.0 per cent in Golkonda samples with a mean of 0.8 whereas it ranged from 0.9 to 1.8 per cent in Amberpet samples with a mean of 1.1.

The metal content varied from 0.7 to 1.0 per cent in Golkonda samples with a mean of 0.8 whereas it varied from 0.9 to 1.3 per cent in Amberpet samples with a mean of 1.0.

The leather content varied from 0.8 to 1.2 per cent in Golkonda samples with a mean of 0.9. It varied from 1.2 to 1.8 per cent in Amberpet samples with a mean of 1.4.

The rubber content ranged from 2.0 to 3.8 per cent in Amberpet samples with a mean of 2.4. It varied from 2.1 to 3.0 per cent in Golkonda samples with a mean of 2.0.

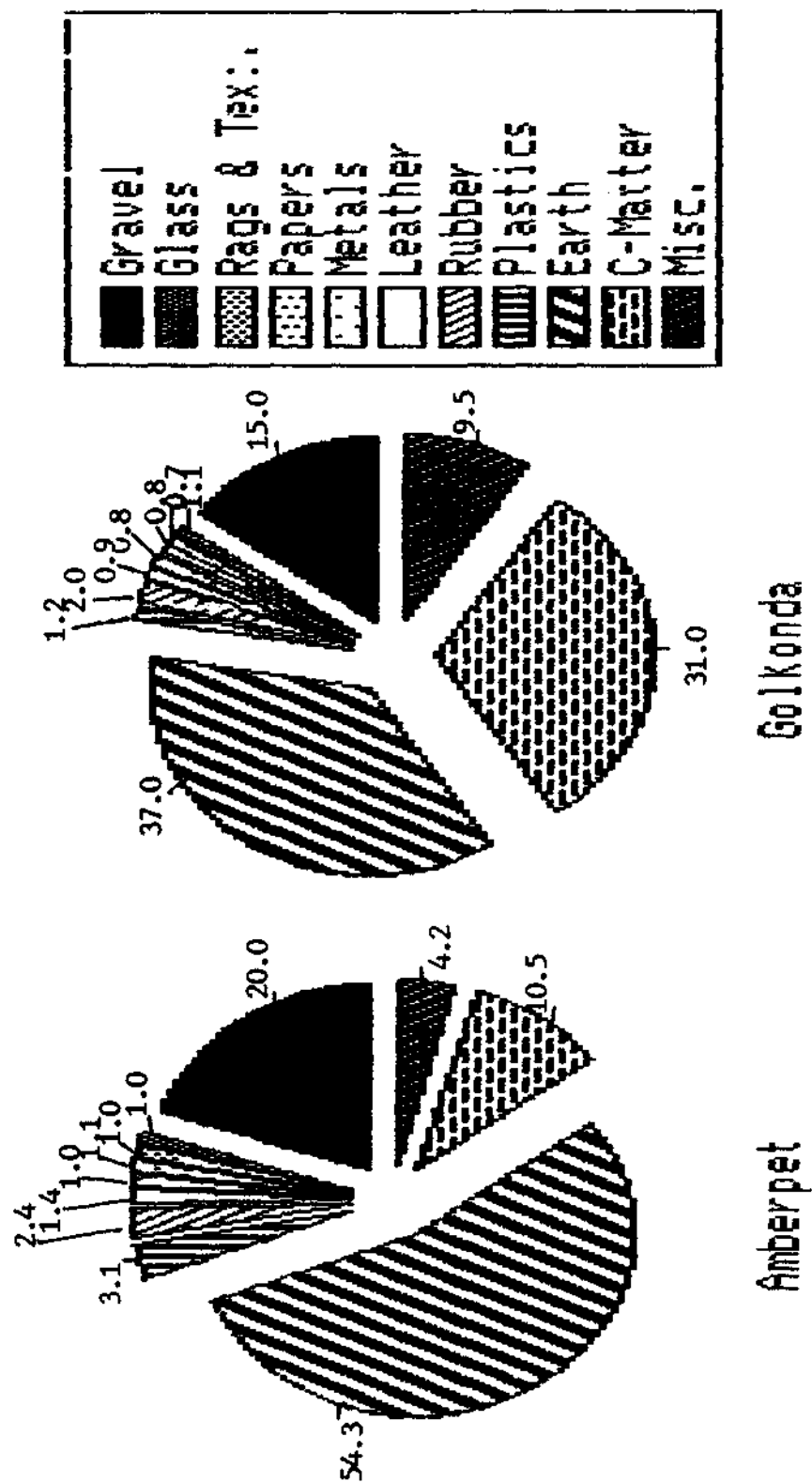


Fig. 3 Histogram showing the composition of stabilized urban solid wastes (%) from two landfill sites

The plastic fraction in the urban solid waste ranged from 0.8 to 1.7 per cent in Golkonda samples with a mean of 1.2. It ranged from 2.1 to 4.4 per cent in Amberpet samples with a mean of 3.1.

The earth and ash content ranged from 23.0 to 42.0 per cent in Golkonda samples with a mean of 37.0. It varied from 50.0 to 65.0 per cent with a mean of 54.3 in Amberpet samples.

The compostable matter ranged from 9.0 to 11.2 per cent in Amberpet samples with a mean of 10.5 whereas in Golkonda samples, it ranged from 29.0 to 35.0 per cent with a mean of 31.0.

The miscellaneous matter content ranged from 3.0 to 5.0 per cent in Amberpet samples with a mean of 4.2. It ranged from 8.0 to 12.0 per cent in Golkonda samples with a mean of 9.5.

The moisture content ranged from 5.0 to 15.0 per cent in Amberpet waste samples with a mean of 11.0. In Golkonda waste samples it ranged from 10.0 to 35.0 per cent with a mean of 30.0.

The density of wastes ranged from 215 to 385 kg m³ in Golkonda samples with a mean of 265. It varied from 255 to 510 kg cu m⁻¹ in Amberpet samples with a mean of 480.

Table 15 : Composition of urban solid wastes generated in Hyderabad city

(All values in per cent by dry weight)												
Characteristics	Fresh solid wastes						Stabilized solid wastes					
	Autonagar			Golkonda			Amberpet			Golkonda		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Gravel	4.50	22.00	12.50	3.20	11.40	6.20	19.00	28.00	20.00	9.00	19.00	15.00
Glass	0.10	2.00	1.00	0.08	0.80	0.50	0.70	1.60	1.00	0.40	1.30	1.10
Rags and textile	0.80	8.00	7.00	1.00	3.50	2.10	0.80	1.40	1.00	0.40	1.10	0.70
Papers	0.70	4.70	2.00	0.90	2.40	2.00	0.90	1.80	1.10	0.60	1.00	0.80
Metals	0.02	2.20	1.00	0.05	2.60	1.30	0.90	1.30	1.00	0.70	1.00	0.80
Leather	0.40	4.20	2.10	0.20	2.10	1.60	1.20	1.80	1.40	0.80	1.20	0.90
Rubber	--	--	--	--	--	--	2.00	3.80	2.40	2.10	3.00	2.00
Plastics	0.05	3.40	1.00	0.50	2.50	1.40	2.10	4.40	3.10	0.80	1.70	1.20
Earth and ash	32.00	64.00	35.00	10.20	24.00	20.50	50.00	65.00	54.30	23.00	42.00	37.00
Compostable matter	16.20	33.00	20.00	20.30	47.50	37.10	9.00	11.20	10.50	29.00	35.00	31.00
Miscellaneous	18.00	22.00	18.40	22.00	35.00	27.30	3.00	5.00	4.20	8.00	12.00	9.50
Moisture	16.00	35.00	27.00	25.00	45.00	38.00	5.00	15.00	11.00	10.00	35.00	30.00
Density	210.00	536.00	410.00	305.00	412.00	365.0	255.00	510.00	480.00	215.00	385.00	265
kg m ⁻³												

4.1.1.3 Stabilized solid waste profiles: The physical composition of the stabilized solid waste profile samples from Amberpet (Plates 18 and 19) and Golkonda landfill sites are presented in Table 16.

The stone content in various samples ranged from 9.5 (GSW-2 at 0-30 cm) to 23.4 per cent (ASW-2 at 0-30 cm depth) with a mean of 17.3. Highest stone content was observed in ASW-2 profile in which it ranged from 20.5 to 23.4 per cent with a mean of 21.73, while the lowest stone content was noticed in GSW-2 profile ranging from 9.5 to 12.0 per cent with a mean of 10.66.

The glass content varied from 0.4 (GSW-1 at 0-30 cm) to 1.6 per cent (ASW-2 at 60-90 cm) with a mean of 1.0. Highest glass content was observed in ASW-2 profile in which it ranged from 0.9 to 1.6 per cent with a mean of 1.23, while the lowest glass content was recorded in GSW-1 profile ranged from 0.4 to 1.5 per cent with a mean of 0.8.

The metal content varied from 0.6 (ASW-3 at 30-60 cm) to 1.7 per cent (GSW-1 at 0-30 cm) with a mean of 1.10. Highest metal content was observed in GSW-1 profile in which it ranged from 1.3 to 1.7 per cent with a mean of 1.46. The lowest metal content was noticed in ASW-3 profile ranging from 0.6 to 0.9 per cent with a mean of 0.76.



Plate 18



Plate 19

Plate 18 & 19 : Stabilized urban solid waste profiles
at Amberpet landfill site

The plastic content ranged from 1.2 (GSW-2 at 0-30 cm) to 4.5 per cent (ASW-1 at 30-60 cm) with a mean of 2.8. Highest plastics content was recorded in ASW-1 profile in which it ranged from 3.6 to 4.5 per cent with a mean of 4.03, while the lowest plastics content was noticed in GSW-2 ranging from 1.2 to 1.8 per cent with a mean of 1.66.

The earth and ash content varied from 23.9 (GSW-1 at 0-30 cm) to 62.5 per cent (ASW-1 at 60-90 cm) with a mean of 44.10. Highest earth and ash content was observed in ASW-1 profile in which it ranged from 54.0 to 62.5 per cent with a mean of 58.76. While the lowest earth and ash content was observed in GSW-1 profile ranging from 23.9 to 35.5 per cent with a mean of 29.83.

The leather, rubber and rags content ranged from 1.8 (GSW-1 at 0-30 cm) to 20.6 per cent (ASW-3 at 0-30 cm) with a mean of 12.0. Highest leather, rubber and rags content was observed in ASW-2 profile in which it ranged from 15.1 to 19.8 per cent with a mean of 17.6, while the lowest values were observed in GSW-1 profile ranging from 1.8 to 8.5 per cent with a mean of 4.33.

The compostable matter varied from 5.7 (ASW-1 at 60-90 cm) to 52.0 per cent (GSW-1 at 0-30 cm) with a mean of 21.70. Highest compostable matter was observed in GSW-1 profile in which it ranged from 40.3 to 52.0

Table 16 : Composition of stabilized urban solid wastes obtained from two major landfill sites at Hyderabad city

===== (Waste components per cent dry weight) =====							
Waste profile depth (cm)	Stone	Glass	Metals	Pla- stics	Earth and ash	Leather rubber, rags and misc.	Compostable matter

ASW-1							
0-30	19.80	1.20	1.30	3.60	54.00	8.90	11.20
30-60	16.50	1.00	1.40	4.50	59.80	9.30	7.50
60-90	18.20	1.40	1.20	4.00	62.50	7.00	5.70
ASW-2							
0-30	23.40	0.90	1.00	4.40	40.00	19.80	10.50
30-60	20.50	1.20	1.10	3.90	46.40	17.90	9.00
60-90	21.30	1.60	0.90	3.20	49.40	15.10	8.50
ASW-3							
0-30	20.50	0.70	0.90	2.10	45.80	20.60	9.40
30-60	22.20	0.90	0.60	2.00	51.00	15.30	8.00
60-90	19.00	1.20	0.80	2.20	52.90	16.80	7.10
GSW-1							
0-30	18.50	0.40	1.70	1.70	23.90	1.80	52.00
30-60	17.00	0.50	1.30	2.60	30.10	2.70	45.80
60-90	10.00	1.50	1.40	2.80	35.50	8.50	40.30
GSW-2							
0-30	9.50	0.60	0.80	1.20	32.10	12.30	43.50
30-60	12.00	1.10	1.00	2.00	40.00	10.00	33.90
60-90	10.50	1.00	1.20	1.80	38.00	13.50	34.00
Range	9.50-	0.40-	0.60-	1.20-	23.90-	1.80-	5.70-
	23.40	1.60	1.70	4.50	62.50	20.60	52.00
Mean	17.30	1.00	1.10	2.80	44.10	12.00	21.70

=====

ASW - Amberpet stabilized solid waste profile

GSW - Golkonda stabilized solid waste profile

per cent with a mean of 46.03, while the lowest compostable matter was observed in ASW-1 profile ranging from 5.7 to 11.2 per cent with a mean of 8.13.

The results on physical characteristics of urban solid wastes (fresh and stabilized) revealed that the wastes are highly heterogeneous in nature. There is no clear trend observed in physical composition of wastes in relation to depth of waste profiles.

4.1.2 Physico-chemical and chemical composition of urban solid wastes

The data pertaining to the physico-chemical and chemical analysis of urban solid wastes and waste profiles are presented in Tables 17 to 21.

4.1.2.1 pH: All the refuse samples were alkaline (pH above 8.5) in reaction and the pH varied from 8.85 (ASW) to 9.6 (GSW) with a mean of 9.1.

In case of waste profiles, it varied from neutral to alkaline. The mean pH of profiles varied from 7.7 (ASW-3) to 8.66 (GSW-1). No significant change in waste pH was observed with depths.

4.1.2.2 Electrical conductivity (EC): The electrical conductivity of 1:50 waste water extract ranged from 130 (ASW) to 500 $\mu S m^{-1}$ (GSW) with a mean of 266.3.

In waste profiles, it varied significantly from 155.33 (ASW-1) to 538.0 u S m^{-1} (GSW-2) and did not differ with depths.

4.1.2.3 Organic carbon: The organic carbon content of wastes ranged from 3.4 (ASW) to 6.3 per cent (GSW) with a mean of 4.22 and in the waste profiles it ranged from 5.3 (ASW-3) to 6.23 per cent (GSW-2).

4.1.2.4 Free calcium carbonate: All the refuse samples were observed to be calcareous in nature with the free CaCO_3 content ranging from 5.0 (AFW) to 10.0 per cent (ASW) with a mean of 6.8 whereas in waste profiles, it ranged from 5.33 (GSW-2) to 7.7 per cent (ASW-1).

4.1.2.5 Cation exchange capacity (CEC): Cation exchange capacity (CEC) of the refuse samples varied from 50 (AFW) to $151 \text{ Cmol (P}^+) \text{ kg}^{-1} \text{ waste}$ (GSW) with a mean of 80 whereas in waste profiles it ranged from 63.33 (ASW-1) to $115.0 \text{ Cmol (P}^+) \text{ kg}^{-1} \text{ waste}$.

4.1.2.6 Organic matter (OM): The organic matter content of wastes ranged from 5.8 (AFW) to 10.9 per cent (GSW) with a mean of 7.3 and in the waste profiles, it ranged non-significantly from 9.14 (ASW-3) to 10.74 per cent (GSW-2).

4.1.2.7 Chemical oxygen demand (COD): The chemical oxygen demand of the solid wastes varied from 89.0 (AFW) to 168.0 mg g^{-1} (GSW) with a mean of 112.3 whereas in

waste profiles, it ranged non-significantly from 118.66 (ASW-3) to 168.0 mg g⁻¹ (GSW-2).

4.1.2.8 Total nitrogen: The total nitrogen content of solid wastes ranged from 0.1 (AFW) to 0.48 per cent (GSW) with a mean of 0.24. In waste profiles it ranged non-significantly from 0.38 (ASW-1) to 0.50 per cent (ASW-2).

4.1.2.9 Total phosphorus: The total phosphorus content of the refuse varied from 0.54 (AFW) to 0.84 per cent (GSW) with a mean of 0.69. In waste profiles, it ranged significantly from 0.14 (ASW) to 0.80 per cent (GSW-1).

4.1.2.10 Total potassium: The total potassium content of refuse ranged from 0.19 (AFW) to 0.45 per cent (GSW) with a mean of 0.28.

In waste profiles it ranged significantly from 0.25 (ASW-1) to 0.46 per cent (GSW-1).

4.1.2.11 Total calcium: The total calcium content of solid wastes ranged from 0.5 (AFW) to 0.84 per cent (ASW) with a mean of 0.68.

In waste profiles it ranged from 0.55 (ASW-2) to 0.75 per cent (ASW-3). Similarly significant differences were also observed with depths.

4.1.2.12 Total magnesium:

The total magnesium content of refuse varied from 0.12 (AFW) to 0.21 per cent (ASW) with a mean of 0.17.

In waste profiles it varied significantly from 0.12 (ASW-2) to 0.18 per cent (ASW-1).

4.1.2.13 Total sodium: The total sodium content of wastes ranged from 0.1 (AFW) to 0.24 per cent (GSW) with a mean of 0.13.

In waste profiles it ranged significantly from 0.13 (ASW-3) to 0.23 per cent (GSW-2). Similarly it differed in depths also.

4.1.2.14 Carbon and nitrogen ratio (C:N): The C:N ratio of refuse varied from 12.41 (ASW) to 36.0 (GFW) with a mean of 23.9. It was higher in fresh wastes than in stabilized wastes.

In stabilized waste profiles it ranged non-significantly from 12.23 (ASW-2) to 14.44 (ASW-1).

4.1.2.15 Volatile matter: The volatile matter in refuse samples ranged from 5.2 (AFW) to 10.1 per cent (GSW) with a mean of 6.7.

In solid waste profiles it ranged non significantly from 8.33 (ASW-1) to 9.66 per cent (ASW-2).

4.1.2.16 Water soluble ions : The mean water soluble potassium of solid wastes ranged from 1240 (AFW) to 2500 ppm (GSW) with a mean of 1698 while in waste profiles, it ranged significantly from 1376.6 (ASW-1) to 2666.6 ppm (GSW-2).

The mean water soluble sodium in wastes ranged from 530 (GFW) to 2400 ppm (GSW) with a mean of 1200. In solid waste profiles, it ranged significantly from 846.6 (ASW-2) to 1966.6 ppm (GSW-2).

The water soluble sulphate content of wastes ranged from 910.0 (AFW) to 3000.0 ppm (GSW) with a mean of 1703. It ranged from 1200.0 (ASW-2) to 3033.3 ppm (GSW-1) in solid waste profiles significantly.

The water soluble chloride content of wastes ranged from 755.0 (AFW) to 1000.0 ppm (GSW) with a mean of 846. In solid waste profiles it ranged from 666.6 (ASW-2) to 966.6 ppm (ASW-3) non-significantly.

4.1.3 Total micronutrients and heavy metals

The data are tabulated in Table 17, 22 and 23.

The total iron content of wastes ranged from 2950 (AFW) to 7162 ppm (ASW) with a mean of 4863. The mean iron content of waste profiles ranged from 7227.3 (GSW-2) to 9026.3 ppm (ASW-2) significantly.

The total manganese content of the solid wastes ranged from 284.0 (AFW) to 520.0 ppm (ASW) with a mean of 379.0. The mean manganese content of waste profiles ranged from 409.3 (ASW-1) to 579.6 ppm (ASW-2) significantly.

The total zinc content of the solid wastes varied from 124 (AFW) to 426.0 ppm (ASW) with a mean of 234.0. The mean zinc content of waste profiles varied from 164.0 (GSW-1) to 295.0 ppm (ASW-2) significantly.

The total copper content of the solid wastes ranged from 82 (AFW) to 143 ppm (ASW) with a mean of 113.0. The mean copper content of waste profiles varied from 91.66 (GSW-1) to 121.0 ppm (ASW-2) non-significantly.

The total lead content of refuse ranged from 88.0 (AFW) to 180.0 ppm (ASW) with a mean of 135.0. The mean lead content of waste profiles varied from 77.0 (GSW-1) to 148.3 ppm (ASW-2) significantly.

The total nickel content of solid wastes varied from 8.5 (AFW) to 16.0 ppm (ASW) ppm with a mean of 12.1. The mean nickel content of waste profiles varied from 12.96 (ASW-1) to 18.96 ppm (GSW-2) non-significantly.

The total cobalt content of solid wastes ranged from 5.0 (ASW and GSW) to 6.0 ppm (GFW and ASW) with a

mean of 5.5. The mean cobalt content of waste profiles ranged from 4.63 (ASW-1) to 5.63 ppm (ASW-3) significantly. Similarly it differed with depths.

The total chromium content of wastes ranged from 16.0 (GSW) to 30.0 ppm (GFW and ASW) with a mean of 25.6. The mean chromium content of waste profiles ranged from 11.0 (ASW-2) to 22.0 ppm (ASW-1) non-significantly.

The total cadmium content of solid wastes varied from 1.0 (GSW) to 3.0 ppm (ASW) with a mean of 2.03. The mean cadmium of waste profiles ranged from 1.06 (ASW-1) to 1.56 ppm (ASW-3) non-significantly.

4.1.4 DTPA-extractable micronutrients and heavy metals

The data are presented in Tables 17, 24 and 25.

The DTPA-Fe content of wastes ranged from 23.0 (ASW) to 63.0 ppm (GFW) with a mean of 51.3. The mean Fe content of solid waste profiles ranged from 53.0 (ASW-2) to 61.3 ppm (GSW-2) non-significantly.

The DTPA-Mn content of wastes ranged from 17.0 (AFW) to 25.0 ppm (GSW) with a mean of 14.8. The mean Mn content of solid waste profiles ranged from 12.66 (ASW-2) to 21.0 ppm (GSW-2) significantly.

The DTPA-Zn content of solid wastes varied from 28.0 (AFW) to 32.0 ppm (GSW and ASW) with a mean of 30.5. The mean Zn content of waste profiles ranged from

29.66 (ASW-2 and GSW-1) to 42.66 ppm (ASW-1) non-significantly.

The DTPA-Cu content of solid wastes ranged from 27.0 (AFW) to 35.0 ppm (GSW) with a mean of 31.5. The mean Cu content of solid waste profiles ranged from 27.66 (ASW-2) to 35.66 ppm (GSW-1) non-significantly.

The DTPA-Pb content of solid wastes ranged from 20.0 (ASW) to 34.0 ppm (GSW) with a mean of 28.8. It ranged from 21.3 (ASW-3) to 31.3 ppm (GSW-2) in waste profiles significantly.

The DTPA-Ni content of solid wastes ranged from 2.0 (AFW and ASW) to 3.1 ppm (GSW) with a mean of 2.3. In waste profiles it ranged from 0.73 (AFW-2) to 1.76 ppm (GSW-2) significantly. Similarly it differed in depths also.

The DTPA-Co content of solid wastes varied from 0.25 (AFW and GSW) to 3.0 ppm (GFW and ASW) with a mean of 0.27. In waste profiles it ranged from 0.76 (GSW-2) to 2.10 ppm (ASW-3) significantly.

The DTPA-Cr content of solid wastes ranged from 0.3 (GSW) to 0.8 ppm (GFW and ASW) with a mean of 0.62. In waste profiles it ranged from 0.41 (GSW-1) to 0.71 ppm (ASW-1) significantly.

The DTPA-Cd content of solid wastes varied from 0.1 (AFW) to 0.18 ppm (ASW) with a mean of 0.13. In

Table 17 : Chemical characteristics of fresh and stabilized urban solid wastes collected from landfill sites at Hyderabad city

S.No.	Characters	Unit	AFW	GFW	GSW	ASW	Range	Mean
1.	pH (1:50)		8.90	9.60	9.20	8.85	8.85-9.60	9.10
2.	EC (1:50)	$\mu S m^{-1}$	130.00	147.00	500.00	288.00	130-500	266.30
3.	Organic carbon	%	3.40	3.60	6.30	3.60	3.4-6.3	4.22
4.	CaCO ₃ (free)	%	5.00	6.00	6.00	10.00	5.0-10.0	6.80
5.	C.E.C.	Cmol (P+) kg ⁻¹	50.00	60.00	151.00	59.00	50-151	80.00
6.	Organic matter	%	5.80	6.20	10.90	6.20	5.8-10.96	7.30
7.	C.O.D.	mg g ⁻¹	89.00	96.00	168.00	96.00	89-168	112.30
8.	Total N	%	0.10	0.11	0.48	0.29	0.1-0.48	0.24
9.	Total P	%	0.54	0.72	0.84	0.69	0.54-0.84	0.69
10.	Total K	%	0.19	0.21	0.45	0.28	0.19-0.45	0.28
11.	Total Ca	%	0.50	0.64	0.75	0.84	0.5-0.84	0.68
12.	Total Mg	%	0.12	0.16	0.17	0.21	0.12-0.21	0.17
13.	Total Na	%	0.10	0.06	0.24	0.13	0.1-0.24	0.13
14.	Volatile substance	%	5.20	5.80	10.10	5.70	5.2-10.1	6.70
15.	C/N	ratio	34.00	36.00	13.12	12.41	12.41-36.0	23.90
16.	Water sol-K	ppm	1240.00	1450.00	2500.00	1600.00	1240-2500	1698.00
17.	Water sol-Na	ppm	640.00	530.00	2400.00	1230.00	530-2400	1200.00
18.	Water sol-SO ₄	ppm	910.00	1100.00	3000.00	1800.00	910-3000	1703.00
19.	Water sol-Cl	ppm	755.00	800.00	1000.00	900.00	755-1000	864.00

Contd...

(Contd... Table 17)

S.No.	Characters	AFW	GFW	GSW	ASW	Range	Mean
-----ppm-----							
20.	Total (HNO ₃ +HClO ₄) micronutrients and heavy metals						
a.	Iron	2950.00	3450.00	5890.00	7162.00	2950-7162	4863.00
b.	Manganese	284.00	300.00	410.00	520.00	284-520	379.00
c.	Zinc	124.00	150.00	234.00	426.00	124-426	234.00
d.	Copper	82.00	98.00	128.00	143.00	82-143	113.00
e.	Lead	88.00	96.00	174.00	180.00	88-180	135.00
f.	Nickel	8.50	10.00	14.00	16.00	8.5-16.0	12.10
g.	Cobalt	5.00	6.00	5.00	6.00	5.0-6.0	5.50
h.	Chromium	26.50	30.00	16.00	30.00	16-30	25.60
i.	Cadmium	2.10	2.00	1.00	3.00	1-3.0	2.03
21.	DTPA-extractable micronutrients and heavy metals						
a.	Iron	59.00	63.00	60.00	23.00	23-63	51.30
b.	Manganese	17.00	19.00	25.00	21.00	17-25	14.80
c.	Zinc	28.00	30.00	32.00	32.00	28-32	30.50
d.	Copper	27.00	30.00	35.00	34.00	27-35	31.50
e.	Lead	26.00	31.00	34.00	20.00	20-34	28.80
f.	Nickel	2.00	2.20	3.10	2.00	2.0-3.1	2.30
g.	Cobalt	0.25	0.30	0.25	0.30	0.25-0.30	0.27
h.	Chromium	0.60	0.80	0.30	0.80	0.3-0.8	0.62
i.	Cadmium	0.10	0.12	0.13	0.18	0.1-0.18	0.13
22.	Cd/Zn ratio	1.70	1.30	0.42	0.7	0.7-1.7	1.03

AFW - Autonagar fresh wastes

GSW - Golkonda stabilized wastes

GFW - Golkonda fresh wastes

ASW - Amberpet stabilized wastes

* - Wastes used in pot culture study

Table 18 : Physico-chemical and chemical characteristics of urban solid wastes at Amberpet and Golkonda landfill sites, Hyderabad city

Profile depth (cm)	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
	pH					
0-30	7.60	7.70	7.60	8.80	7.90	7.92
30-60	7.80	7.90	7.60	8.60	8.50	8.08
60-90	8.00	8.00	7.90	8.60	9.20	8.34
Mean	7.80	7.86	7.70	8.66	8.53	

SEd + of two depth means - 0.22 ; L.S.D. (0.05) - NS
SEd + of two profile means - 0.17 ; L.S.D. (0.05) - 0.40

Electrical conductivity ($\mu S m^{-1}$)

0-30	98.00	164.00	226.00	420.00	525.00	286.60
30-60	170.00	205.00	328.00	495.00	415.00	322.60
60-90	198.00	278.00	296.00	384.00	674.00	366.00
Mean	155.33	215.66	283.33	433.00	538.00	

SEd + of two depth means - 59.04; L.S.D. (0.05) - NS
SEd + of two profile means - 45.73; L.S.D. (0.05) - 105.46

Organic carbon (%)

0-30	6.99 (12.05)	7.31 (12.60)	5.00 (8.62)	5.90 (10.14)	6.20 (10.68)	6.28 (10.81)
30-60	3.84 (6.62)	6.54 (11.27)	5.91 (10.18)	6.10 (10.51)	5.70 (9.82)	5.61 (9.68)
60-90	5.91 (10.18)	4.62 (7.98)	5.00 (8.62)	6.50 (11.20)	6.80 (11.72)	5.76 (9.94)
Mean	5.58 (9.61)	6.15 (10.61)	5.30 (9.14)	6.16 (10.61)	6.23 (10.74)	

SEd + of two depth means - 0.870; L.S.D. (0.05) - NS
(1.491)
SEd + of two profile means - 0.674; L.S.D. (0.05) - NS
(1.16)

Cation exchange capacity (Cmol (P+) kg^{-1} waste)

0-30	74.00	75.00	65.00	92.00	112.00	83.60
30-60	55.00	69.00	70.00	104.00	105.00	80.60
60-90	61.00	54.00	60.00	110.00	128.00	82.60
Mean	63.33	66.00	65.00	102.00	115.00	

SEd + of two depth means - 8.63; L.S.D. (0.05) - NS
SEd + of two profile means - 6.69; L.S.D. (0.05) - 15.42

Figures in parenthesis under organic carbon are calculated vlaues
of organic matter - O.M (%) = O.C (%) x 1.724

Table 19 : Chemical characteristics of urban solid wastes at Amberpet and Golkonda landfill sites, Hyderabad city

Profile depth (cm)	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
	Volatile matter (%)					
0-30	10.50	12.00	7.60	8.30	8.36	9.35
30-60	5.60	9.90	8.90	8.60	7.44	8.08
60-90	8.90	7.10	7.60	9.40	9.58	8.51
Mean	8.33	9.66	8.03	8.76	8.46	

Sed + of two depth means - 1.42 - L.S.D. (0.05) - NS
Sed + of two profile means - 1.10 - L.S.D. (0.05) - NS

Chemical oxygen demand mg g^{-1}

0-30	156.52	163.40	111.80	154.00	169.00	150.94
30-60	86.00	146.20	132.40	169.00	150.00	136.72
60-90	132.44	103.20	111.80	172.00	185.00	140.88
Mean	124.98	137.60	118.66	165.00	168.00	

SEd + of two depth means - 20.49; L.S.D. (0.05) - NS
SEd + of two profile means - 15.87; L.S.D. (0.05) - NS

CaCO₃-free (%)

0-30	8.00	7.40	8.20	5.40	5.50	6.90
30-60	7.50	7.20	7.10	6.00	4.80	5.52
60-90	7.60	6.50	7.00	6.20	5.70	6.60
Mean	7.70	7.03	7.43	5.86	5.33	

SEd + of two depth means - 0.394; L.S.D. (0.05) - NS
SEd + of two profile means - 0.305; L.S.D. (0.05) - 0.704

C/N ratio

0-30	17.40	11.98	12.19	14.00	14.09	13.93
30-60	12.80	12.59	12.30	13.26	14.20	13.02
60-90	13.13	12.15	12.50	12.74	13.07	12.71
Mean	14.44	12.23	12.33	13.33	13.78	

SEd $\pm$ of two depth means = 0.95; L.S.D. (0.05) = NS
SEd $\pm$ of two profile means = 0.74; L.S.D. (0.05) = NS

Table 20 : Total nutrient content of urban solid wastes at
Amberpet and Golkonda landfill sites, Hyderabad city

=====						
Wastes						
Profile	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	Mean
depth (cm)						

----- (%) -----						
Nitrogen						
0-30	0.40	0.61	0.41	0.42	0.44	0.45
30-60	0.30	0.52	0.48	0.46	0.40	0.43
60-90	0.45	0.38	0.40	0.51	0.52	0.45
Mean	0.38	0.50	0.43	0.46	0.45	
SEd + of two depth means - 0.065; - L.S.D. (0.05) - NS						
SEd + of two profile means - 0.051; - L.S.D. (0.05) - NS						
Phosphorus						
0-30	0.17	0.21	0.22	0.76	0.73	0.42
30-60	0.15	0.20	0.26	0.81	0.61	0.41
60-90	0.10	0.19	0.19	0.84	0.82	0.43
Mean	0.14	0.20	0.22	0.80	0.72	
SEd + of two depth means - 0.049; L.S.D. (0.05) - NS						
SEd + of two profile means - 0.038; L.S.D. (0.05) - 0.088						
Potassium						
0-30	0.20	0.34	0.30	0.41	0.36	0.32
30-60	0.22	0.30	0.36	0.46	0.32	0.33
60-90	0.35	0.28	0.29	0.51	0.49	0.38
Mean	0.25	0.31	0.32	0.46	0.39	
SEd + of two depth means - 0.048; L.S.D. (0.05) - NS						
SEd + of two profile means - 0.037; L.S.D. (0.05) - 0.085						
=====						

Contd...

(Contd...Table 20)

=====						
Wastes						
Profile	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	Mean
depth (cm)						
----- (%) -----						

Sodium						
0-30	0.12	0.14	0.12	0.21	0.22	0.16
30-60	0.16	0.12	0.11	0.19	0.20	0.16
60-90	0.21	0.15	0.17	0.24	0.26	0.21
Mean	0.16	0.13	0.13	0.21	0.23	

SEd $\pm$ of two depth means - 0.013; L.S.D. (0.05) - 0.031SEd $\pm$ of two profile means - 0.010; L.S.D. (0.05) - 0.024

Calcium						
0-30	0.65	0.40	0.71	0.64	0.58	0.60
30-60	0.72	0.54	0.74	0.74	0.62	0.67
60-90	0.80	0.72	0.80	0.81	0.68	0.76
Mean	0.72	0.55	0.75	0.73	0.63	

SEd $\pm$ of two depth means - 0.038; L.S.D. (0.05) - 0.088SEd $\pm$ of two profile means - 0.029; L.S.D. (0.05) - 0.068

Magnesium						
0-30	0.15	0.11	0.17	0.14	0.12	0.13
30-60	0.18	0.13	0.16	0.16	0.15	0.15
60-90	0.21	0.13	0.15	0.17	0.16	0.16
Mean	0.18	0.12	0.16	0.15	0.14	

SEd $\pm$ of two depth means - 0.012; L.S.D. (0.05) - NSSEd $\pm$ of two profile means - 0.0095; L.S.D. (0.05) - 0.022

=====

Table 21 : Water soluble ions in urban solid wastes at Amberpet and Golkonda landfill sites, Hyderabad city

=====						
Profile depth (cm)	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
	-----ppm-----					
	Potassium					
0-30	1300.00	1900.00	1870.00	2300.00	2600.00	1994.00
30-60	1260.00	1750.00	1940.00	1800.00	2000.00	1750.00
60-90	1570.00	1640.00	1670.00	2800.00	3400.00	2216.00
Mean	1376.60	1763.30	1826.60	2300.00	2666.60	

SEd + of two depth means - 299.0; L.S.D. (0.05) - NS

SEd + of two profile means - 231.0; L.S.D. (0.05) - 530.00

Sodium

0-30	1000.00	820.00	980.00	1800.00	2000.00	1320.00
30-60	1400.00	770.00	1000.00	1600.00	1800.00	1314.00
60-90	1990.00	950.00	1520.00	2100.00	2100.00	1732.00
Mean	1463.30	846.60	1166.60	1833.30	1966.60	

SEd + of two depth means - 301.0; L.S.D. (0.05) - NS

SEd + of two profile means - 233.0; L.S.D. (0.05) - 537.00

Chloride

0-30	800.00	700.00	1100.00	1000.00	800.00	880.00
30-60	600.00	800.00	900.00	900.00	600.00	760.00
60-90	900.00	500.00	900.00	800.00	1000.00	820.00
Mean	766.60	666.00	966.60	900.00	800.00	

SEd + of two depth means - 123.00; L.S.D. (0.05) - NS

SEd + of two profile means - 95.00; L.S.D. (0.05) - NS

Sulphate

0-30	1200.00	1400.00	2100.00	3100.00	2800.00	2120.00
30-60	1800.00	1200.00	1800.00	2800.00	2100.00	1940.00
60-90	2100.00	1000.00	2200.00	3200.00	3100.00	2320.00
Mean	1700.00	1200.00	2033.30	3033.30	2666.60	

SEd + of two depth means - 264.0; L.S.D. (0.05) - NS

SEd + of two profile means - 204.0; L.S.D. (0.05) - 470.00

=====

Table 22 : Total micronutrient content in urban solid wastes at Amberpet and Golkonda landfill sites, Hyderabad city

Profile depth (cm)	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
	ppm					
	Iron					
0-30	5800.00	9431.00	8342.00	8550.00	6020.00	7628.60
30-60	6704.00	8701.00	9012.00	8854.00	7542.00	8162.60
60-90	5945.00	8947.00	8741.00	9031.00	8120.00	8156.70
Mean	6149.60	9026.30	8698.30	8811.60	7227.00	

SEd + of two depth means - 456.99; L.S.D. (0.05) - NS

SEd + of two profile means - 353.98; L.S.D. (0.05) - 816.30

Manganese

0-30	463.00	621.00	530.00	344.00	424.00	476.40
30-60	395.00	597.00	525.00	475.00	475.00	493.40
60-90	370.00	521.00	580.00	515.00	513.00	499.80
Mean	409.30	579.60	545.00	444.60	470.60	

SEd + of two depth means - 50.38; L.S.D. (0.05) - NS

SEd + of two profile means - 39.02; L.S.D. (0.05) - 89.99

Zinc

0-30	215.00	320.00	241.00	148.00	225.00	229.80
30-60	205.00	290.00	261.00	180.00	215.00	230.20
60-90	242.00	275.00	211.00	164.00	230.00	224.40
Mean	220.16	295.00	237.60	164.00	223.30	

SEd + of two depth means - 17.25; L.S.D. (0.05) - NS

SEd + of two profile means - 13.36; L.S.D. (0.05) - 30.82

Copper

0-30	101.00	123.00	73.00	68.00	124.00	97.80
30-60	123.00	135.00	98.00	92.00	121.00	113.80
60-90	95.00	105.00	110.00	115.00	105.00	106.00
Mean	106.30	121.00	93.66	91.66	116.60	

SEd + of two depth means - 13.77; L.S.D. (0.05) - NS

SEd + of two profile means - 10.66; L.S.D. (0.05) - NS

Table 23 : Total heavy metal content in urban solid wastes at
Amberpet and Golkonda landfill sites, Hyderabad city

Profile depth (cm)	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
	----- ppm -----					
	Lead					
0-30	104.00	174.00	125.00	58.00	145.00	121.20
30-60	115.00	145.00	135.00	78.00	134.00	121.40
60-90	121.00	126.00	141.00	95.00	128.00	122.20
Mean	113.30	148.30	133.60	77.00	135.66	
SEd +	of two depth means - 13.78; L.S.D. (0.05) - NS					
SEd +	of two profile means - 10.67; L.S.D. (0.05) - 24.62					
	Nickel					
0-30	14.00	12.10	18.50	16.70	19.40	16.14
30-60	11.40	16.40	12.50	12.50	17.40	14.04
60-90	13.50	14.00	14.00	18.50	20.10	16.02
Mean	12.96	14.16	15.00	15.90	18.96	
SEd +	of two depth means - 1.86; L.S.D. (0.05) - NS					
SEd +	of two profile means - 1.44; L.S.D. (0.05) - NS					
	Cobalt					
0-30	4.90	6.50	6.00	5.90	5.10	5.68
30-60	5.00	5.30	5.20	5.10	4.70	5.06
60-90	4.00	5.00	5.70	5.30	4.60	4.92
Mean	4.63	5.60	5.63	5.43	4.80	
SEd +	of two depth means - 0.294; L.S.D. (0.05) - 0.68					
SEd +	of two profile means - 0.228; L.S.D. (0.05) - 0.52					
	Chromium					
0-30	64.00	40.00	19.00	32.00	15.40	34.08
30-60	31.00	25.00	12.00	14.50	20.40	20.58
60-90	22.00	11.00	16.00	17.50	21.40	17.50
Mean	39.00	25.33	15.66	21.33	18.93	
SEd +	of two depth means - 8.36; L.S.D. (0.05) - NS					
SEd +	of two profile means - 6.47; L.S.D. (0.05) - NS					
	Cadmium					
0-30	1.00	1.50	2.00	1.70	1.00	1.44
30-60	1.00	1.10	1.20	1.30	1.20	1.16
60-90	1.20	1.20	1.50	1.40	1.30	1.32
Mean	1.06	1.26	1.56	1.46	1.16	
SEd +	of two depth means - 0.177; L.S.D. (0.05) - NS					
SEd +	of two profile means - 0.137; L.S.D. (0.05) - NS					

Table 24 : DTPA-extractable micronutrient content in urban solid wastes at Amberpet and Golkonda landfill sites, Hyderabad city

Profile depth	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
	-----ppm-----					
	Iron					
0-30	54.00	52.00	51.00	54.00	61.00	54.40
30-60	56.00	49.00	61.00	49.00	58.00	54.60
60-90	50.00	58.00	57.00	62.00	65.00	58.40
Mean	53.30	53.00	56.00	55.00	61.30	

SEd + of two depth means - 3.77; L.S.D. (0.05) - NS

SEd + of two profile means - 2.92; L.S.D. (0.05) - NS

	Manganese					
0-30	17.00	11.00	12.00	14.00	23.00	15.40
30-60	15.40	13.00	15.00	18.00	19.00	16.00
60-90	11.00	14.00	16.00	17.00	21.00	15.80
Mean	14.33	12.66	14.33	16.33	21.00	

SEd + of two depth means - 1.99; L.S.D. (0.05) - NS

SEd + of two profile means - 1.54; L.S.D. (0.05) - 3.56

	Zinc					
0-30	55.00	27.00	21.00	22.00	32.00	31.40
30-60	32.00	34.00	42.00	39.00	42.00	37.80
60-90	41.00	28.00	37.00	28.00	24.00	31.60
Mean	42.66	29.66	33.33	29.66	32.66	

SEd + of two depth means - 7.72; L.S.D. (0.05) - NS

SEd + of two profile means - 5.98; L.S.D. (0.05) - NS

	Copper					
0-30	35.00	36.00	29.00	37.00	34.00	34.20
30-60	31.00	28.00	27.00	31.00	30.00	29.40
60-90	24.00	19.00	32.00	39.00	29.00	28.60
Mean	30.00	27.66	29.33	35.66	31.00	

SEd + of two depth means - 3.83; L.S.D. (0.05) - NS

SEd + of two profile means - 2.96; L.S.D. (0.05) - NS

Table 25 : DTPA-extractable heavy metals and Cd/Zn ratio in urban solid wastes at Amberpet and Golkonda landfill sites, Hyderabad city

=====						
Wastes						
Profile	-----					
depth (cm)	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	Mean

----- ppm -----						
Lead						
0-30	35.00	24.00	20.00	18.00	34.00	26.20
30-60	27.00	29.00	25.00	22.00	31.00	26.80
60-90	31.00	26.00	19.00	27.00	29.00	26.40
Mean	31.00	26.30	21.30	22.30	31.30	
SEd + of two depth means - 3.13; L.S.D. (0.05) - NS						
SEd + of two profile means - 2.42; L.S.D. (0.05) - 5.59						
Nickel						
0-30	2.00	0.65	1.30	1.40	2.40	1.55
30-60	1.50	0.84	0.94	0.95	1.30	1.10
60-90	0.90	0.71	0.82	0.74	1.60	0.95
Mean	1.46	0.73	1.02	1.03	1.76	
SEd + of two depth means - 0.235; L.S.D. (0.05) - 0.542						
SEd + of two profile means - 0.182; L.S.D. (0.05) - 0.420						
Cobalt						
0-30	1.20	1.30	2.70	1.60	0.80	1.52
30-60	1.00	1.50	1.60	1.20	0.90	1.24
60-90	1.50	1.70	2.00	1.00	0.60	1.36
Mean	1.23	1.50	2.10	1.26	0.76	
SEd + of two depth means - 0.268; L.S.D. (0.05) - NS						
SEd + of two profile means - 0.207; L.S.D. (0.05) - 0.478						
=====						

Contd...

(Contd...Table 25)

Profile depth (cm)	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
	ppm					
	Chromium					
0-30	0.81	0.45	0.34	0.31	0.77	0.53
30-60	0.70	0.47	0.41	0.42	0.63	0.52
60-90	0.64	0.54	0.47	0.50	0.54	0.53
Mean	0.71	0.48	0.40	0.41	0.64	
SEd $\pm$ of two depth means - 0.077; L.S.D. (0.05) - NS						
SEd $\pm$ of two profile means - 0.060; L.S.D. (0.05) - 0.138						
	Cadmium					
0-30	0.16	0.12	0.15	0.11	0.10	0.12
30-60	0.10	0.08	0.10	0.10	0.05	0.08
60-90	0.11	0.06	0.06	0.07	0.08	0.07
Mean	0.12	0.08	0.10	0.09	0.07	
SEd $\pm$ of two depth means - 0.0144; L.S.D. (0.05) - 0.033						
SEd $\pm$ of two profile means - 0.0112; L.S.D. (0.05) - 0.025						
	Cd/Zn ratio (%)					
0-30	0.460	0.46	0.82	1.14	0.44	0.66
30-60	0.480	0.37	0.45	0.72	0.55	0.51
60-90	0.490	0.43	0.71	0.85	0.56	0.71
Mean	0.476	0.42	0.66	0.90	0.51	

solid waste profiles it ranged from 0.07 ppm (GSW-2) to 0.12 ppm (ASW-1) significantly. Similarly it differed significantly with depths also.

4.1.5 Cadmium and Zinc ratio (Cd/Zn)

The Cd/Zn ratio of solid wastes ranged from 0.7 (ASW) to 1.7 per cent (AFW) with a mean of 1.03. In waste profiles it ranged from 0.42 (ASW-2) to 0.9 per cent (GSW-1) (Tables 17 and 25).

4.1.6 Relative availability of metals

The data are presented in Tables 26 to 29.

Among all the micronutrients and heavy metals in wastes, the availability of Cu, Ni, Pb and Zn was relatively more as compared to others whereas Mn, Cd, Co, Cr and Fe were less available.

The relative availability of Fe of solid wastes ranged from 0.32 (ASW) to 2.0 per cent (AFW) with a mean of 1.3. The mean relative available Fe content of waste profiles ranged from 0.58 (ASW-2) to 0.87 per cent (ASW-1).

The relative availability of Mn content of solid wastes ranged from 4.0 (ASW) to 6.3 per cent (GFW) with a mean of 5.6. In waste profiles, it ranged from 2.2 (ASW-2) to 4.5 per cent (GSW-2).

The relative availability of Zn content of solid wastes varied from 7.51 (ASW) to 22.6 per cent (AFW) with a mean of 15.9. In waste profiles, it ranged from 10.1 (ASW-2) to 19.4 per cent (ASW-1).

The relative availability of copper content in solid wastes ranged from 23.77 (ASW) to 33.0 per cent (AFW) with a mean of 28.7. In waste profiles, it ranged from 20.1 (ASW-3) to 40.6 per cent (GFSW-1).

The relative availability of lead in solid wastes varied from 11.1 (ASW) to 32.3 per cent (GFW) with a mean of 23.1. In waste profiles, it ranged from 16.0 (ASW-3) to 29.2 per cent (GSW-1).

The relative availability of nickel in solid wastes ranged from 12.5 (ASW) to 23.5 per cent (AFW) with a mean of 20.0 whereas in waste profiles, it ranged from 5.2 (ASW-2) to 11.3 per cent (ASW-1).

The relative availability of cobalt content in solid wastes was found to be 5 per cent while in waste profiles it ranged from 15.9 (GSW-3) to 36.9 per cent (ASW-3).

The relative availability of chromium in solid wastes varied from 1.8 (GSW) to 2.6 per cent (ASW and GFW) with a mean of 2.3 whereas in waste profiles it ranged from 2.6 (ASW-1) to 3.5 per cent (GSW-2).

Table 26 : Relative availability of micronutrients and heavy metals in urban solid wastes collected from landfill sites at Hyderabad city

Sl.No. Organic wastes	Relative availability (%) ⁺									
1. FYM [*]	Mn > (52.90)	Zn > (15.80)	Cu > (12.80)	Pb > (10.00)	Ni > (10.00)	Co > (5.00)	Fe > (0.22)	Cr > (0.00)	Cd > (0.00)	
2. ASW [*]	Cu > (23.77)	Ni > (12.50)	Pb > (11.10)	Zn > (7.51)	Cd > (6.00)	Co > (5.00)	Mn > (4.00)	Cr > (2.60)	Fe > (0.32)	
3. GSW [*]	Cu > (27.34)	Ni > (22.11)	Pb > (19.50)	Zn > (13.67)	Cd > (13.00)	Mn > (6.09)	Co > (5.00)	Cr > (1.80)	Fe > (1.00)	
4. GFW [*]	Pb > (32.30)	Cu > (30.61)	Ni > (22.00)	Zn > (20.00)	Mn > (6.30)	Cd > (6.01)	Co > (5.00)	Cr > (2.60)	Fe > (1.80)	
5. AFW	Cu > (33.00)	Pb > (29.50)	Ni > (23.50)	Zn > (22.60)	Mn > (6.00)	Co > (5.00)	Cd > (4.70)	Cr > (2.30)	Fe > (2.00)	

+ Values in parenthesis are DTPA/HNO₃ ratios expressed as percentages for metals extracted from all the organic wastes studied.

* Wastes used in pot culture study.

Table 27 : Relative availability (%) of micronutrients in urban solid wastes at Amberpet and Golkonda landfill sites, Hyderabad city

Profile depth (cm)	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
Iron						
0-30	0.93	0.55	0.61	0.63	1.01	0.75
30-60	0.83	0.56	0.67	0.55	0.76	0.67
60-90	0.84	0.64	0.65	0.68	0.80	0.72
Mean	0.87	0.58	0.64	0.62	0.86	
Manganese						
0-30	3.67	1.77	2.26	4.06	5.42	3.40
30-60	3.79	2.17	2.85	3.78	4.00	3.30
60-90	2.97	2.68	2.75	3.30	4.09	3.20
Mean	3.50	2.20	2.60	3.70	4.50	
Zinc						
0-30	25.58	8.43	8.71	14.86	14.20	14.40
30-60	15.60	11.72	16.09	21.66	19.53	16.90
60-90	16.94	10.18	17.53	17.00	10.43	14.40
Mean	19.40	10.10	14.10	17.80	14.70	
Copper						
0-30	34.65	29.26	39.72	54.40	27.41	37.10
30-60	24.80	20.74	27.55	33.69	24.79	26.30
60-90	25.26	18.09	29.09	33.91	27.61	26.80
Mean	28.20	22.70	20.10	40.60	26.60	

Table 28 : Relative availability (%) of heavy metals in urban solid wastes at Amberpet and Golkonda landfill sites, Hyderabad city

Profile depth (cm)	Wastes					Mean
	ASW-1	ASW-2	ASW-3	GSW-1	GSW-2	
	Lead					
0-30	33.65	13.79	16.00	31.03	23.44	23.60
30-60	23.47	20.00	18.51	28.20	23.13	22.70
60-90	25.61	20.60	13.47	28.42	22.65	22.10
Mean	27.60	18.10	16.00	29.20	23.00	
	Nickel					
0-30	14.28	5.37	7.02	8.38	12.37	9.50
30-60	13.15	5.12	7.52	7.60	7.47	8.20
60-90	6.60	5.07	5.85	4.00	7.96	5.90
Mean	11.30	5.20	6.80	6.60	9.30	
	Cobalt					
0-30	24.48	20.00	45.00	27.11	15.68	26.40
30-60	20.20	28.30	30.76	23.52	19.14	24.30
60-90	37.50	34.00	35.08	18.86	13.04	22.70
Mean	27.30	27.40	36.90	23.20		
	Chromium					
0-30	1.26	1.12	1.78	0.96	5.00	2.00
30-60	2.25	1.88	3.41	2.89	3.00	2.70
60-90	2.90	4.90	2.93	2.85	2.57	3.20
Mean	2.10	2.60	2.70	2.20	3.50	
	Cadmium					
0-30	16.00	8.00	7.50	6.47	10.00	9.10
30-60	10.00	7.20	8.30	7.69	4.16	7.50
60-90	9.16	5.00	4.00	5.00	6.15	5.90
Mean	11.70	6.70	6.60	6.40	6.70	

Table 29 Mean relative availability of micronutrients and heavy, metals in stabilized urban solid wastes collected from Amberpet and Golkonda landfill sites, Hyderabad city

S.No.	Organic waste profiles	Mean relative availability																
		Cu	>	Pb	>	Co	>	Zn	>	Cd	>	Ni	>	Mn	>	Cr	>	Fe
1	ASW-1	(28.2)		(27.6)		(27.3)		(19.4)		(11.7)		(11.3)		(3.5)		(2.1)		(0.87)
2	ASW-2	(27.4)		(27.7)		(18.1)		(10.1)		(6.7)		(5.2)		(2.6)		(2.2)		(0.58)
3	ASW-3	(36.9)		(20.1)		(16.0)		(14.1)		(6.8)		(6.6)		(2.7)		(2.6)		(0.64)
4	GSW-1	(40.6)		(29.2)		(23.2)		(17.6)		(6.6)		(6.4)		(3.7)		(2.2)		(0.62)
5	GSW-2	(26.6)		(23.0)		(15.9)		(14.7)		(9.3)		(6.7)		(4.5)		(3.5)		(0.86)

Values in parenthesis are DTPA/HNO₃ ratios expressed as percentage for metals extracted from all the waste profiles studied.

The relative availability of cadmium in solid wastes ranged from 4.7 (AFW) to 13 per cent (GSW) with a mean of 7.4. In waste profiles it ranged from 6.4 (GSW-1) to 11.7 per cent (ASW-1).

4.2 URBAN SOLID WASTE CHARACTERISTICS AT AMBERPET LANDFILL SITE

This landfill site was chosen to represent a situation wherein urban solid wastes have been disposed of at the site for the past 29 years and presently abandoned for the past nine years. Therefore, the urban solid waste can be considered as stabilized and the data on characteristics of the wastes are presented in Tables 30 to 32.

At the other two landfill sites selected for the study the urban solid wastes are continually being disposed of currently including the period of the present study. Hence, the urban wastes can be considered as not stabilized.

4.2.1 Physico-chemical properties

The data are presented in Table 30.

Waste samples for the study were collected from the locations where soil profiles were dug to study the profile characteristics at four locations within the landfill site and the stabilized waste samples were obtained from these profile by collecting the waste

samples accumulated between soil surface and 30 cm above.

The pH (1:2) of the wastes was alkaline and ranged from 8.0 (waste sample 1) to 8.6 (waste sample 4) with a mean of 8.25. The electrical conductivity of the solid wastes (1:2) ranged from 0.97 (waste sample 4) to 4.48 d S m⁻¹ (waste sample-3) with a mean of 2.85.

The cation exchange capacity of wastes ranged from 58.0 (waste sample 1) to 74.3 Cmol (P⁺) kg⁻¹ waste (waste sample-2) with a mean of 65.87.

The exchangeable calcium content of wastes ranged from 8.1 (waste sample-2) to 8.6 Cmol (P⁺) kg⁻¹ waste (waste sample-4) with a mean of 8.36. The exchangeable magnesium content of wastes ranged from 3.7 (waste sample-4) to 4.25 Cmol (P⁺) kg⁻¹ waste (waste sample-3) with a mean of 3.98. The exchangeable potassium content of wastes ranged from 1.66 (waste sample-1) to 3.14 Cmol (P⁺) kg⁻¹ waste (waste sample-1) with a mean of 2.45. Whereas the exchangeable sodium content ranged from 0.32 (waste sample-1) to 0.54 Cmol (P⁺) kg⁻¹ waste (waste sample-3) with a mean of 0.43.

The per cent base saturation of wastes ranged from 19.67 (waste sample-2) to 26.5 (waste sample-3) with a mean of 23.3.

Table 30 : Physico-chemical and chemical characteristics of stabilized urban solid wastes collected from Amberpet landfill site, Hyderabad city

Waste sample	pH (1:2)	EC (1:2) d S m ⁻¹	Base saturation (%)	C.E.C. Cmol (P) kg waste	Exchangeable cations (Cmol (P+) kg waste)				O.C. (%)
					Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	
1	8.00	3.84	24.96	58.00	8.50	4.00	1.66	0.32	1.44
2	8.20	2.14	19.67	74.30	8.10	4.00	2.10	0.42	1.56
3	8.20	4.48	26.50	61.00	8.25	4.25	3.14	0.54	1.48
4	8.60	0.97	22.30	70.20	8.60	3.70	2.90	0.46	1.50
Range	8.00 to 8.60	0.97 to 4.48	19.67 to 26.50	58.00 to 74.30	8.10 to 8.60	3.70 to 4.25	1.66 to 3.14	0.32 to 0.54	1.44 to 1.56
Mean	8.25	2.85	23.30	65.87	8.36	3.98	2.45	0.43	1.49

4.2.2 Organic carbon and total nutrients

The organic carbon content of solid wastes ranged from 1.44 (waste sample 1) to 1.56 per cent (waste sample-2) with a mean of 1.49.

The total nitrogen content of wastes ranged from 0.12 (waste sample-2) to 0.13 per cent (waste samples 1, 2 and 4) with a mean of 0.127. The total phosphorus content ranged from 0.14 (waste sample-2) to 0.17 per cent (waste sample-4) with a mean of 0.15, whereas total potassium content ranged from 0.28 (waste sample 1 and 4) to 0.295 per cent (waste sample 3) with a mean of 0.286 (Table 31).

The C/N ratio computed from the organic carbon and total nitrogen contents of the wastes ranged from 11.0 (waste sample 1) to 12.3 (waste sample 3) with a mean of 11.7.

4.2.3 Plant available nutrients

The data are presented in Table 31.

The available nitrogen content of wastes ranged from 98.0 (waste sample-1) to 104.0 ppm (waste sample-2) with a mean of 101.70. The phosphorus content ranged from 28.0 (waste sample-3) to 30.0 ppm (waste sample-2) with a mean of 28.7. The potassium ranged from 2400.0 (waste sample-1 and 4) to 2850.0 ppm (waste sample-3) with a mean of 2587.50. The NH_4OAc extractable sodium

Table 31 : Total, available and water soluble nutrients in stabilized urban solid wastes collected from Amberpet landfill site, Hyderabad city

Waste samples	Total (%)			Available (ppm)		NH ₄ OAC extractable		Water soluble (ppm)			
	N	P	K	C/N ratio	N	P	K	K	Na	SO ₄ ²⁻	Cl ⁻
1	0.130	0.16	0.280	11.00	98.00	28.00	2400.00	1256.00	1600.00	1104.00	1681.00
2	0.130	0.14	0.290	12.00	104.00	30.00	2700.00	837.00	1870.00	740.00	1820.00
3	0.120	0.15	0.295	12.30	102.00	28.00	2850.00	1395.00	1625.00	1269.00	1931.00
4	0.130	0.17	0.280	11.50	103.00	29.00	2400.00	907.00	1250.00	799.00	1110.00
Range	0.120 to 0.130	0.14 to 0.17	0.280 to 0.295	11.00 to 12.30	98.00 to 104.00	28.00 to 30.00	2400.00 to 2700.00	837.00 to 1395.00	1250.00 to 1870.00	740.00 to 1104.00	1110.00 to 1681.00
Mean	0.127	0.15	0.286	11.70	101.70	28.75	2587.50	1098.70	1601.20	978.00	1635.50

ranged from 837.0 (waste sample-2) to 1395.0 ppm (waste sample-3) with a mean of 1098.7.

4.2.4 Water soluble ions

The data are presented in Table 31.

The water soluble potassium content in wastes ranged from 1250 (waste sample-4) to 1870 ppm (waste sample-2) with a mean of 1601.2. Similarly the sodium concentration ranged from 740 (waste sample-2) to 1269 ppm (waste sample-3) with a mean of 978. The sulphate content ranged from 1110 (waste sample 4) to 1931 ppm (waste sample-3) with a mean of 1635.5. The chloride content ranged from 324.0 (waste sample-2) to 640.0 ppm (waste sample-1) with a mean of 473.5.

4.2.5 Total micronutrients and heavy metals content of wastes

The data are presented in Table 32.

The total iron content ranged from 5526.0 (waste sample-1) to 9253 ppm (waste sample-2) with a mean of 7874.5. The manganese content varied from 250.0 (waste sample- 4) to 680 ppm (waste sample-2) with a mean of 465.0 whereas the zinc content ranged from 152.4 (waste sample- 4) to 359.1 ppm (waste sample-2) with a mean of 253.5. The copper content varied from 63.0 (waste sample- 4) to 134.0 ppm (waste sample-3) with a mean of 95.0.

The lead content of wastes varied from 66.4 (waste sample- 4) to 186.8 ppm (waste sample-2) with a mean of 124.2. The nickel content ranged from 12.0 (waste sample-1) to 24.2 ppm (waste sample-2) with a mean of 16.7. The cobalt content ranged from 5.0 (waste sample-1) to 7.0 ppm (waste sample-2) with a mean of 6.0. The cadmium content ranged from 1.0 (waste sample-1) to 2.0 ppm (waste samples-2, 3 and 4) with a mean of 1.75 whereas chromium content ranged from 19.0 (waste sample -3) to 73.0 ppm (waste sample-1) with a mean of 40.25.

In general, among the total micronutrients and heavy metal contents of wastes, the iron content was highest and cadmium content was the least and the wastes contained varying quantities of other heavy metals namely nickel, lead, cobalt and chromium.

4.2.6 DTPA-extractable micronutrients and heavy metals in wastes

The data are presented in Table 32.

The iron content of wastes ranged from 52.0 (waste sample- 1) to 57.0 ppm (waste sample- 2) with a mean of 54.75. The manganese content varied from 12.0 (waste samples- 3 and 4) to 18.4 ppm (waste sample-1) with a mean of 13.8. The zinc content ranged from 22.0 (waste sample-3) to 61.0 ppm (waste sample-1) with a

mean of 33. The copper content ranged from 31.2 (waste sample-3) to 39.0 ppm (waste sample-4) with a mean of 36.4.

The lead content ranged from 14.4 (waste sample 4) to 34.0 ppm (waste sample-1) with a mean of 22.4. The nickel content varied from 0.4 (waste sample-1 and 2) to 1.44 ppm (waste sample-3) with a mean of 0.88 whereas cobalt ranged from 1.41 (waste sample-1) to 3.0 ppm (waste sample-3) with a mean of 1.87. The cadmium content ranged from 0.12 (waste sample-4) to 0.18 ppm (waste sample-1) with a mean of 0.15. The chromium content varied from 0.23 (waste sample-3) to 0.85 ppm (waste sample 1) with a mean of 0.46.

In general, among all the DTPA extractable micronutrients and heavy metals in solid wastes, iron was occurring in higher concentrations and cadmium the least.

4.2.7 Relative availability (%) of metals in wastes

The data are presented in Table 32.

The mean relative availability, calculated as a ratio of the DTPA extractable concentration to total concentration ($\text{HNO}_3 + \text{HClO}_4$ extractable) expressed in percentage followed the following order:

Table 32 : Micronutrient and heavy metal contents and their relative availability in stabilized urban solid wastes collected from Amberpet landfill site, Hyderabad city

Waste samples		Elements								
		Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	Cr
		Total (HNO ₃ + HClO ₄) ppm								
1		5526.00	470.00	220.70	107.00	100.80	12.00	5.00	1.00	73.00
2		9253.00	680.00	359.10	134.00	186.80	24.20	7.00	2.00	35.00
3		8162.00	460.00	282.10	76.00	142.80	15.10	6.00	2.00	19.00
4		8556.00	250.00	152.40	63.00	66.40	15.50	6.00	2.00	34.00
Range		5526.00	250.00	152.40	63.00	66.40	12.00	5.00	1.00	19.00
		to	to	to	to	to	to	to	to	to
		9253.00	680.00	359.10	134.00	186.80	24.20	7.00	2.00	73.00
Mean		7874.50	465.00	253.50	95.00	124.20	16.70	6.00	1.75	40.25
		DTPA-Extractable ppm								
1		52.00	18.40	61.00	37.20	34.00	0.40	1.41	0.18	0.85
2		57.00	12.80	26.00	38.30	21.00	0.40	1.46	0.14	0.40
3		54.00	12.00	22.00	31.20	20.50	1.44	3.00	0.18	0.23
4		56.00	12.00	23.00	39.00	14.40	1.30	1.70	0.12	0.36
Range		52.00	12.00	22.00	31.20	14.40	0.40	1.41	0.12	0.23
		to	to	to	to	to	to	to	to	to
		57.00	18.40	61.00	36.40	34.00	1.44	3.00	0.18	0.85
Mean		54.75	13.80	33.00	36.40	22.40	0.88	1.89	0.15	0.46
	Cd/ Zn	Relative Availability (%)								
1	0.45	0.94	3.91	27.63	34.76	33.73	3.30	28.20	18.00	1.16
2	0.55	0.61	1.88	7.24	28.58	11.24	1.65	20.85	7.00	1.14
3	0.70	0.66	2.60	7.79	41.00	14.35	9.50	50.00	9.00	1.21
4	1.31	0.65	4.80	15.00	61.90	21.60	8.30	28.30	6.00	1.00
Range	0.45	0.61	1.88	7.24	28.58	11.24	1.65	20.85	6.00	1.00
	to	to	to	to	to	to	to	to	to	to
	1.31	0.94	4.80	27.63	61.90	33.73	9.50	50.00	18.00	1.21
Mean	0.75	0.71	3.29	14.41	41.56	20.23	5.68	31.83	10.00	1.12

Cu	>	Co	>	Pb	>	Zn	>	Cd	>	Ni	>
(41.56)		(31.83)		(20.23)		(14.41)		(10.00)		(5.68)	

Mn	>	Cr	>	Fe
(3.29)		(1.12)		(0.715)

4.2.8 Cadmium-Zinc ratio (%)

The Cd/Zn ratio of wastes ranged from 0.45 (waste sample-1) to 1.31 per cent (waste sample-4) per cent with a mean of 0.75 (Table 32).

4.3 IMPACT OF WASTE DISPOSAL ON SOIL CHARACTERISTICS AT AMBERPET LANDFILL SITE

At this site urban solid wastes were continually disposed for more than two decades and abandoned for the last nine years. It represents a situation where there is an attainment of a higher degree of stabilization of the waste overlay accumulating on the soil surface. Additionally this also provides an ideal situation for studying the impact of long term waste disposal on soil characteristics. Seven soil profiles were exposed at this site and samples were collected at 30 cm interval upto a total depth of 210 cm.

The soil profiles from 1 to 4 were influenced directly by the urban solid wastes accumulating over the soil surface (Plates 20 to 23), whereas soil profiles A and B were affected only by the runoff water from landfill site flowing onto the adjacent land for more

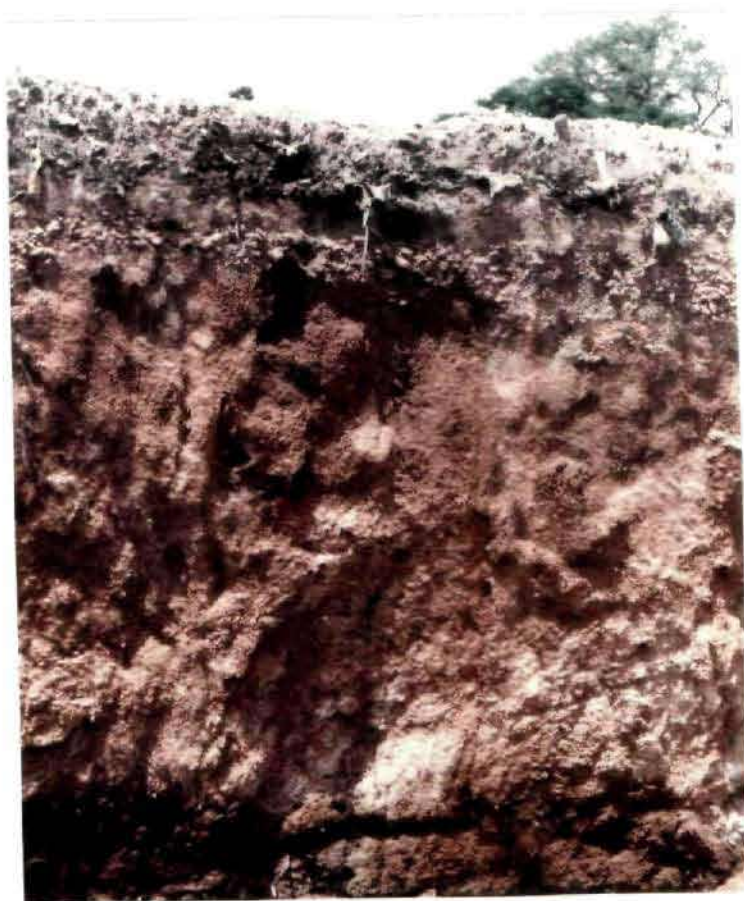


Plate 20 : A view of the soil profile-1 under the urban solid waste dumps at Amberpet landfill site

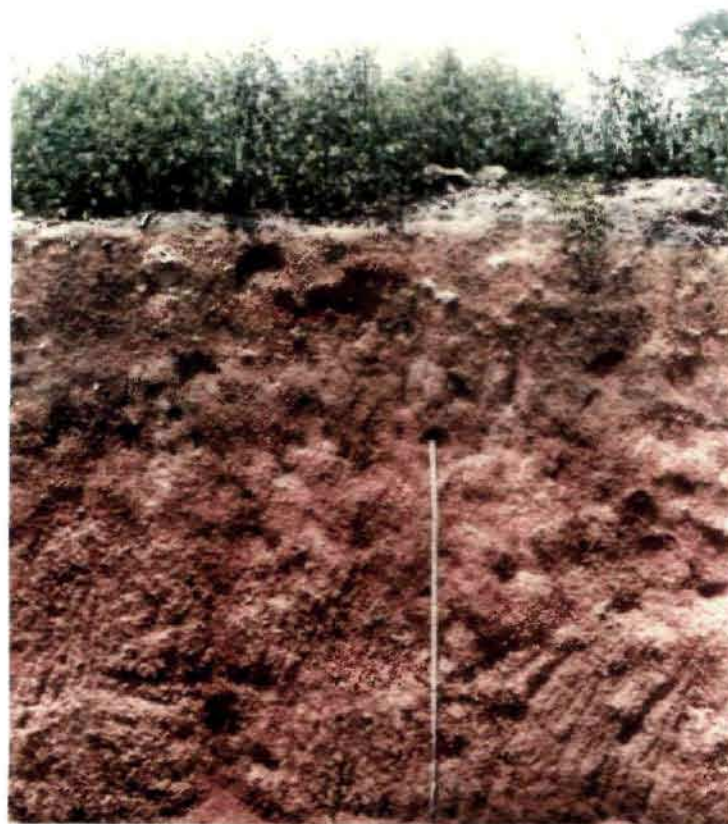


Plate 21 : A view of the soil profile-2 under the urban solid waste dumps at Amberpet landfill site

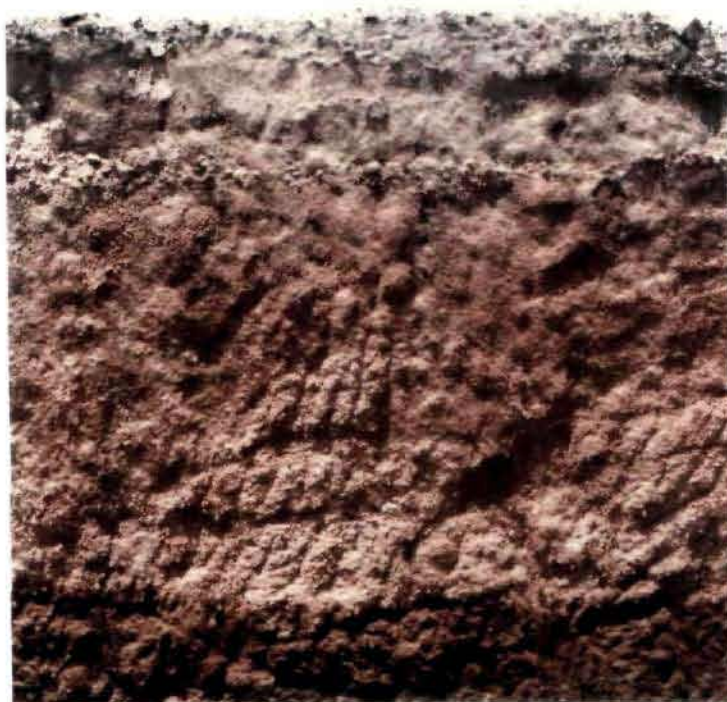


Plate 22 : A view of the soil profile-3 under the urban solid waste dumps at Amberpet landfill site



Plate 23 : A view of the soil profile-4 under
the urban solid waste dumps at
Amberpet landfill site

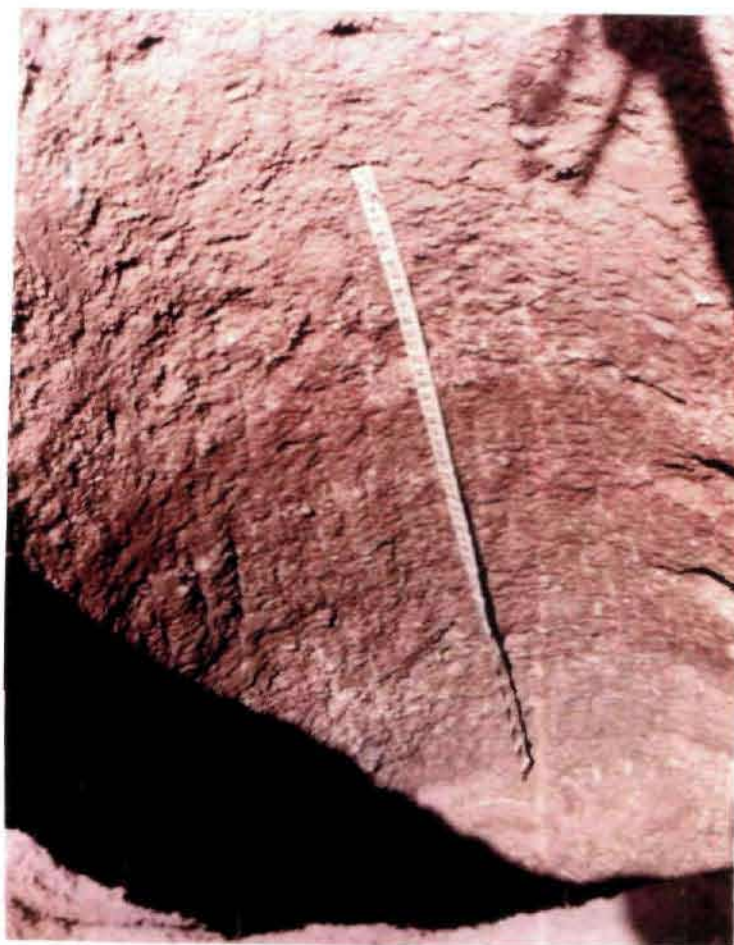


Plate 24 : A view of the soil profile-C (control) not influenced by the disposal of urban solid wastes

than 20 years. The profile C is control (Plate 24), which is not affected either by urban solid wastes or by runoff water from landfill site. The methodology and procedure adopted in collecting these samples is given in Section 3.1.2.2.

The results on physical, physico-chemical and chemical properties of the soil as influenced by on land waste disposal and runoff from the landfill are presented here.

4.3.1 Particle size distribution

The data are presented in Table 33.

The mean sand content of soil profiles ranged from 65.51 (profile A) to 80.54 per cent (profile C). In all the profiles the sand content decreased when compared to control (C). At the different depths the lowest sand content of 51.0 per cent (60-90 cm) in profile 1 and highest content of 89 per cent in profiles 1, 2 and C (180-210 cm) were recorded. The sand content decreased upto a certain depth (90 cm) of the profiles and increased thereafter with soil depth.

The mean silt content of soil profiles ranged from 8.31 (profile C) to 15.45 per cent (profile 4). It increased in all the profiles as compared to control (Profile C). Among different depths, the highest silt content of 27.6 per cent was recorded in profile 4 at

90-120 cm depth. The silt content decreased as soil depth increased.

The mean clay content of all the soil profiles increased over control (profile C). The mean clay content of profiles ranged from 11.14 (profile C) to 21.48 per cent (Profile A). Among soil depths, the clay content ranged from 3.0 (profile C at 180-210 cm) to 37.0 per cent (60-90 cm and 120-150 cm in profiles 1 and 2 respectively). The clay content increased upto a certain depth (90 cm) of the profile and decreased thereafter with depth.

In general sand content decreased whereas silt and clay contents increased in all the profiles as compared to control.

a) Soil colour

The Munsell soil colour values of soil profiles are presented in Table 34. The colour of the surface 0-30 and 60-90 cm depth of the soil profile was affected due to accumulation of urban solid wastes on the soil surface as compared to control.

b) Soil textural class

The textural class of soil profiles according to the USDA system is presented in Table 34.

The soil texture ranged from sandy clay loam to sand.

Table 33: Particle size distribution of soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil profiles	Depth (cm)							Mean
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	
	%							
	Sand							
Profile-1	75.00	71.00	51.00	55.00	59.00	81.00	89.00	68.71
Profile-2	67.00	75.00	55.00	59.00	79.00	81.00	89.00	72.14
Profile-3	83.00	79.60	51.40	63.40	79.40	87.40	87.40	75.94
Profile-4	82.40	75.40	57.40	51.40	77.40	72.40	77.40	70.54
Profile-A	64.40	70.40	64.40	63.40	51.00	70.00	75.00	65.51
Profile-B	67.00	69.00	61.00	60.00	59.00	75.00	80.00	67.28
Profile-C	83.40	78.00	53.00	85.40	87.00	88.00	89.00	80.54
Silt								
Profile-1	14.00	10.00	12.00	12.00	12.00	6.60	4.00	10.08
Profile-2	12.00	10.60	8.00	18.00	8.00	8.00	4.00	9.80
Profile-3	8.00	7.80	14.00	12.00	10.00	6.00	5.60	9.05
Profile-4	8.60	10.60	19.60	27.60	13.60	16.60	11.60	15.45
Profile-A	16.40	10.00	9.00	7.00	12.60	19.00	18.00	13.00
Profile-B	18.00	12.00	14.00	15.00	20.00	6.00	7.00	13.14
Profile-C	9.60	8.00	12.00	7.60	6.00	7.00	8.00	8.31
Clay								
Profile-1	11.00	19.00	37.00	33.00	29.00	12.40	7.00	21.20
Profile-2	21.00	14.40	37.00	23.00	13.00	11.00	7.00	18.05
Profile-3	9.00	12.60	34.60	24.60	10.60	6.60	7.00	15.00
Profile-4	9.00	14.00	23.00	21.00	9.00	11.00	11.00	14.00
Profile-A	19.60	19.60	26.60	29.60	37.00	11.00	7.00	21.48
Profile-B	15.00	19.00	25.00	25.00	21.00	19.00	13.00	19.57
Profile-C	7.00	14.00	35.00	7.00	7.00	5.00	3.00	11.14

Table 34 : Soil colour and textural class of soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil profiles	Depth (cm)						
	0-30	30-60	60-90	90-120	120-150	150-180	180-210
Soil colour (Munsell, moist)							
Profile-1	2.5 YR 4/2	2.5 YR 5/4	2.5 YR 3/4	2.5 YR 3/4	10.0 R 4/4	5.0 YR 5/6	2.5 YR 7
Profile-2	5.0 YR 4/4	5.0 YR 4/3	2.5 YR 3/4	10.0 YR 4/4	2.5 YR 4/4	2.5 YR 4/4	5.0 YR 5/3
Profile-3	5.0 YR 5/2	5.0 YR 4/2	2.5 YR 3/4	2.5 YR 3/4	2.5 YR 4/4	5.0 YR 4/4	5.0 YR 5/3
Profile-4	2.5 YR 4/2	2.5 YR 4/2	10.0 R 3/6	2.5 YR 2.5/4	2.5 YR 3/4	2.5 YR 4/4	5.0 YR 4/4
Profile-A	2.5 YR 4/2	5.0 YR 4/2	2.5 YR 3/4	2.5 YR 3/4	2.5 YR 3/4	2.5 YR 4/4	2.5 YR 4/4
Profile-B	5.0 YR 4/2	2.5 YR 5/4	2.5 YR 3/4	2.5 YR 3/4	2.5 YR 4/4	2.5 YR 3/4	2.5 YR 3/4
Profile-C	5.0 YR 5/4	2.5 YR 5/4	2.5 YR 3/4	7.5 YR 4/4	7.5 YR 4/4	7.5 YR 4/4	7.5 YR 3/4
Soil textural class (USDA)							
Profile-1	sl	sl	sc	sc	sc	ls	s
Profile-2	sc	sl	sc	sc	sl	ls	s
Profile-3	ls	sl	sc	sc	ls	s	s
Profile-4	ls	sl	sc	l	ls	sl	sl
Profile-A	sl	sl	sc	sc	sc	sl	ls
Profile-B	sl	sl	sc	sc	sc	sl	ls
Profile-C	ls	sl	sc	s	s	s	s
sl = sandy loam l = loam sc = sandy clay loam s = sand ls = loamy sand sc = sandy clay							

4.3.2 Physico-chemical properties

The data on physico-chemical properties of soil profiles are presented in Table 35.

4.3.2.1 Soil reaction (pH): The mean soil pH of all the profiles was alkaline in reaction and ranged from 7.80 (profile C) to 9.94 (profile A). Among all the soil profiles, highest increase in soil pH was observed in profile A as compared to control. In general, in all the profiles the pH was more than was observed in the control. The pH at different depths varied from 7.2 (0-30 cm) in profile C to 10.4 (0-30 cm) in profile A. No particular trend was observed in change of pH in relation to depth in the soil profiles.

4.3.2.2 Electrical conductivity (EC): The mean electrical conductivity of all the soil profiles ranged from 0.19 (profile C) to 7.0 d S m^{-1} (profile 4). In all the profiles, the EC values at all the soil depths were more than the values recorded in the control (Fig.4). The EC values at different depths ranged from a low value of 0.09 (180-210 cm depth in profile C) to a high of 10.86 d S m^{-1} (90-120 cm in profile 4) (Plate 25).

In general, the EC decreased with soil depth. However, the influence of waste disposal or runoff water increased the EC values of soils.

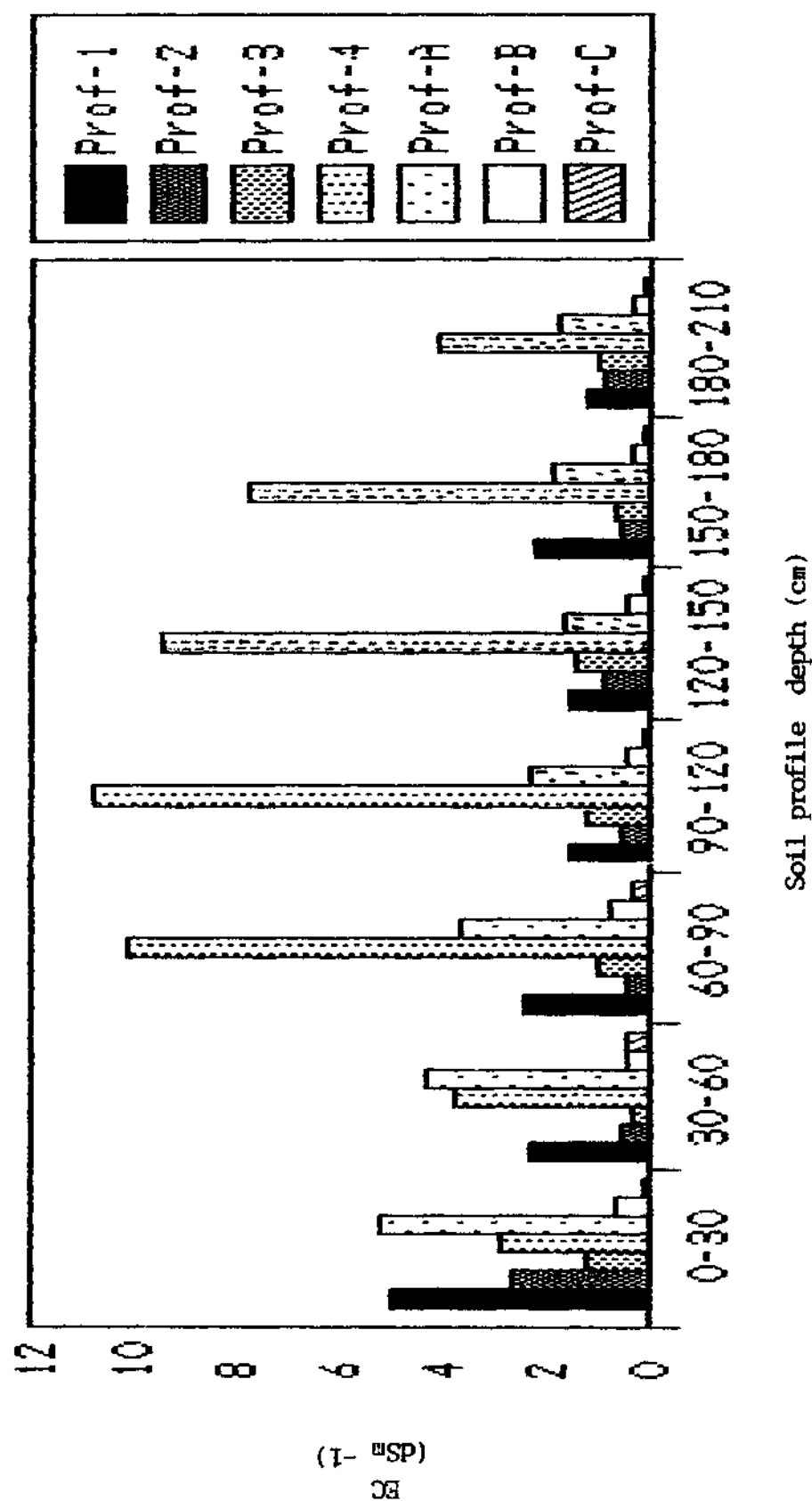


Fig. 4 Electrical conductivity of soil profiles influenced by disposal of urban solid wastes at Amberpet landfill site

4.3.2.3 Cation exchange capacity (CEC): The mean CEC values of all soil profiles were more as compared to control. The values ranged from 4.98 (profile C) to 14.21 C mol (P⁺) kg⁻¹ soil (profile A). At different depths the values ranged from 1.6 (180-210 cm) in profile C to 21.0 C mol (P⁺) kg⁻¹ soil (130-150 cm) in profile A. The CEC increased to a certain depth (90 cm) and later on decreased with increase in soil depth. The pattern of change in CEC was similar to that of the distribution of clay and silt in the soil profiles.

4.3.2.4 Base saturation (%) : The mean per cent base saturation of all the soil profiles increased as compared to the control. It ranged from 75.38 (profile C) to 92.54 per cent (profile 4). At different depths, it ranged from 44.7 (120-150 cm) in profile A to 98.88 per cent (0-30 cm) in profile 1.

In general, no specific trend of change in base saturation of the soil could be observed with the increase in depth of the soil. However, the base saturation values increased in soils occurring under landfill site as well as soils influenced by landfill runoff.

4.3.2.5 Exchangeable cations

a) Calcium

The mean soil exchangeable calcium increased in all the profiles over control. On the contrary it decreased in profile A. It ranged from 0.4 (profile A) to

5.28 C mol (P^+) kg^{-1} soil (profile 2). Among the different soil depths, exchangeable Ca ranged from nil (150-210 cm) in profile A to 11.5 C mol (P^+) kg^{-1} soil (60-90 cm) in profile 3. In profile A, it decreased from 1.0 (0-30 cm) to nil C mol (P^+) kg^{-1} at 150 to 210 cm depth.

In general, the exchangeable Ca increased to a certain soil depth (90 cm), thereafter, it decreased as the depth increased.

b) **Magnesium:** The mean exchangeable magnesium content of soil profiles ranged from 0.15 (profile A) to 2.5 C mol (P^+) kg^{-1} soil (profile 3). It increased in all the profiles over control but decreased in profile A over control. At different soil depths it ranged from nil (0-30 and 150-210 cm) in profile A to 5.0 C mol (P^+) kg^{-1} soil (60-90 cm) in profile 3.

In general, the exchangeable Ca content of soil increased upto 90 cm depth and thereafter it decreased with increase in soil depth.

c) **Potassium:** The mean exchangeable potassium in soil profiles ranged from 0.06 (profile A) to 3.40 C mol (P^+) kg^{-1} soil (profile 4). In all the soil profiles the exchangeable K increased over control. In relation to soil depth, the exchangeable K content ranged from 0.04 (180-210 cm) in profile C to 7.3 C mol (P^+) kg^{-1} soil

Table 35 : Physico-chemical characteristics of soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil profiles	Depth (cm)							
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	Mean
pH								
Profile-1	8.00	8.40	8.30	8.00	8.00	8.10	8.10	8.12
Profile-2	8.10	8.00	7.90	8.10	7.90	8.00	8.00	8.00
Profile-3	8.20	8.60	8.10	7.90	8.00	8.10	7.90	8.11
Profile-4	8.40	8.50	8.90	8.50	8.80	7.90	7.70	8.38
Profile-A	10.40	10.20	10.00	9.80	9.70	9.70	9.80	9.94
Profile-B	6.80	7.50	8.00	8.00	8.20	8.20	8.40	7.87
Profile-C	7.20	7.50	7.60	7.90	8.00	8.20	8.20	7.80
Electrical conductivity (d S m^{-1})								
Profile-1	5.06	2.33	2.41	1.62	1.54	2.27	1.27	2.35
Profile-2	2.64	0.60	0.41	0.61	0.93	0.61	0.87	0.95
Profile-3	1.25	0.32	1.02	1.22	1.41	0.65	1.03	0.98
Profile-4	2.87	3.84	10.14	10.86	9.49	7.86	4.15	7.00
Profile-A	5.20	4.40	3.65	2.30	1.65	1.85	1.80	2.97
Profile-B	0.63	0.49	0.43	0.40	0.45	0.36	0.30	0.43
Profile-C	0.16	0.40	0.35	0.14	0.11	0.10	0.09	0.19
Per cent base saturation								
Profile-1	98.88	96.00	90.57	90.80	96.03	94.55	88.44	93.61
Profile-2	85.68	93.17	89.61	94.00	89.50	95.00	87.50	90.63
Profile-3	94.74	94.62	93.60	93.40	94.60	72.34	98.10	92.20
Profile-4	96.00	93.68	88.14	91.22	97.70	92.02	89.05	92.54
Profile-A	85.40	84.35	72.90	52.36	44.70	95.20	97.50	86.08
Profile-B	76.38	69.64	58.65	75.71	73.05	83.03	91.21	76.05
Profile-C	65.62	90.86	85.20	93.59	96.20	89.50	81.60	75.38
Cation exchange capacity (Cmol (P+) kg^{-1} soil)								
Profile-1	9.85	11.30	15.60	13.70	12.10	7.90	4.50	10.70
Profile-2	15.30	8.20	15.60	12.70	7.90	6.80	5.68	10.30
Profile-3	5.90	9.30	20.50	14.70	7.90	4.70	4.90	9.70
Profile-4	7.10	9.50	14.60	13.10	6.10	7.90	7.40	9.38
Profile-A	13.50	15.40	18.50	19.00	21.00	8.50	3.60	14.21
Profile-B	7.20	8.50	10.40	11.20	9.50	8.90	5.50	8.74
Profile-C	3.20	8.10	15.40	2.81	2.00	1.80	1.60	4.98

Contd...

(Contd...Table 35)

Soil profiles	Depth (cm)							Mean
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	
Exchangeable cations (Cmol (P+) kg ⁻¹ soil)								
Calcium								
Profile-1	1.25	3.75	6.75	5.50	6.50	4.00	2.50	4.32
Profile-2	3.25	3.75	8.25	9.25	5.00	5.00	2.50	5.28
Profile-3	2.00	4.50	11.50	8.00	4.25	2.00	2.75	5.00
Profile-4	4.50	2.00	2.20	2.25	1.75	3.00	2.25	2.56
Profile-A	1.00	0.70	0.50	0.40	0.20	0.00	0.00	0.40
Profile-B	2.75	3.25	3.20	5.00	4.50	4.00	2.90	3.65
Profile-C	1.75	4.50	8.50	2.00	1.50	1.30	1.10	2.95
Magnesium								
Profile-1	0.75	2.50	3.50	4.75	1.75	2.00	1.00	2.32
Profile-2	2.25	1.75	3.75	2.00	1.50	1.00	1.50	1.96
Profile-3	0.50	2.25	5.00	4.50	2.75	1.00	1.50	2.50
Profile-4	0.50	1.00	1.75	1.25	0.75	2.50	2.75	1.50
Profile-A	0.00	0.50	0.30	0.20	0.10	0.00	0.00	0.15
Profile-B	2.50	2.00	2.50	3.00	2.00	3.00	1.90	2.41
Profile-C	0.25	2.75	4.50	0.50	0.30	0.20	0.10	1.22
Potassium								
Profile-1	7.00	4.30	3.40	1.75	2.95	1.10	0.110	2.94
Profile-2	7.10	1.98	1.73	0.40	0.23	0.20	0.500	1.73
Profile-3	2.45	1.77	1.90	0.43	0.23	0.14	0.097	1.00
Profile-4	1.60	4.30	7.30	6.50	2.00	1.00	1.100	3.40
Profile-A	0.99	2.60	0.30	0.35	0.19	3.40	1.870	1.38
Profile-B	0.21	0.14	0.09	0.13	0.08	0.09	0.057	0.11
Profile-C	0.08	0.07	0.08	0.08	0.06	0.05	0.040	0.06
Sodium								
Profile-1	0.75	0.30	0.480	0.44	0.420	0.370	0.370	0.445
Profile-2	0.51	0.16	0.190	0.29	0.340	0.260	0.470	0.317
Profile-3	0.64	0.28	0.800	0.80	0.560	0.260	0.460	0.542
Profile-4	0.22	1.60	2.500	1.95	1.460	0.770	0.490	1.280
Profile-A	9.54	7.10	12.400	9.00	8.900	4.700	1.640	7.620
Profile-B	0.04	0.53	0.310	0.35	0.360	0.300	0.160	0.270
Profile-C	0.02	0.04	0.043	0.05	0.064	0.062	0.066	0.040

Depth (cm)	pH	EC d S m ⁻¹	CEC (Cmol ⁺ (P+) Kg soil/ waste	Exchangeable cations (Cmol (P+) kg ⁻¹ soil/ waste				
				Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	
Waste 180-210	8.0-8.6	0.97- 3.84	58.0-74.30	8.10- 8.60	3.70-4.25	1.66-3.14	0.32-0.54	
Soil 0- 30	8.0-8.4	1.25- 5.06	7.1-15.30	1.25- 4.50	0.50-2.25	1.60-7.10	0.22-0.75	
pro- file 30- 60	8.0-8.6	0.32- 3.84	9.3-11.30	2.00- 4.50	1.00-2.25	1.77-4.30	0.16-1.60	
60- 90	7.9-8.3	0.41-10.14	14.6-20.50	2.20-11.50	1.75-5.00	1.73-7.30	0.19-2.50	
90-120	7.5-8.1	0.61-10.86	12.7-14.70	2.25- 9.25	1.25-4.75	0.40-6.50	0.29-1.95	
120-150	7.8-8.0	0.93- 9.49	6.1-12.10	1.75- 6.50	0.75-2.75	0.23-2.95	0.34-1.46	
150-180	7.9-8.1	0.61- 7.86	4.7- 7.90	3.00- 5.00	1.00-2.50	0.14-1.10	0.26-0.77	
180-210	7.7-8.0	0.87- 4.17	4.5- 7.40	2.25- 2.75	1.00-2.75	0.09-1.10	0.37-0.49	

Plate 25 : Soil profile (1 to 4) characteristics (range)
under urban solid wastes at Amberpet landfill site-
physico-chemical properties



(60-90 cm) in profile 4. The exchangeable K content decreased as soil depth increased.

d) Sodium: The mean exchangeable sodium content of soil profiles ranged from 0.04 (profile C) to 7.62 C mol (P⁺) kg⁻¹soil (profile A) . Increase in exchangeable Na content was recorded in all the profiles when compared to control. In soil depths, it ranged from 0.02 (0-30 cm) in profile C to 12.4 C mol (P⁺) kg⁻¹soil (60-90 cm) in profile A.

In general, the exchangeable Na decreased with soil depth and followed the pattern of distribution of silt and clay contents.

In profile A, the content of other exchangeable cations like calcium, magnesium and potassium were low as compared to the other soil profiles (Table 35).

4.3.2.6 Calcium : Magnesium ratio: The mean soil Ca/Mg ratio ranged from 1.0 (profile A) to 5.27 (profile C). In all the profiles it decreased as compared to the control (profile C). Whereas in depths it ranged from nil (0-30 and 150-210 cm) in profile A to 11.0 (180-210 cm) in profile C. The Ca/Mg ratio decreased as soil depth increased (Table 36)

4.3.3 Organic carbon, free CaCO_3 and total nitrogen

The data are presented in Table 36.

The mean organic carbon content of all the soil profiles increased over control. It ranged from 0.047 (profile C) to 0.611 per cent (profile A). In relation to soil depth, it ranged from 0.009 (180-210 cm) in profile C to 1.50 per cent (0-30 cm) in profile 2 and decreased as soil depth increased (Fig.5)

The mean free CaCO_3 content of the soil profiles varied from 0.57 (profile A) to 4.28 per cent (profile 4). Increase in free CaCO_3 content was evident in all the profiles, except in one, profile A as compared to control. In all the soil profile depths it ranged from nil (150-210 cm) in profile A to 9.5 per cent (30-60 and 180-210 cm) in profiles 3 and 4. There was no clear cut trend in free CaCO_3 content with change in soil depth (Table 36).

The mean total nitrogen content of all the profiles was more than it was in control (Table 36). It ranged from 0.0036 (profile C) to 0.044 per cent (profile A). Among soil depths, the lowest and highest values ranged from 0.0004 (180-120 cm) in profile C to 0.12 per cent (0-30 cm) in profile 2. The total nitrogen content was more at different depths in soils which were influenced by urban solid waste disposal or run off

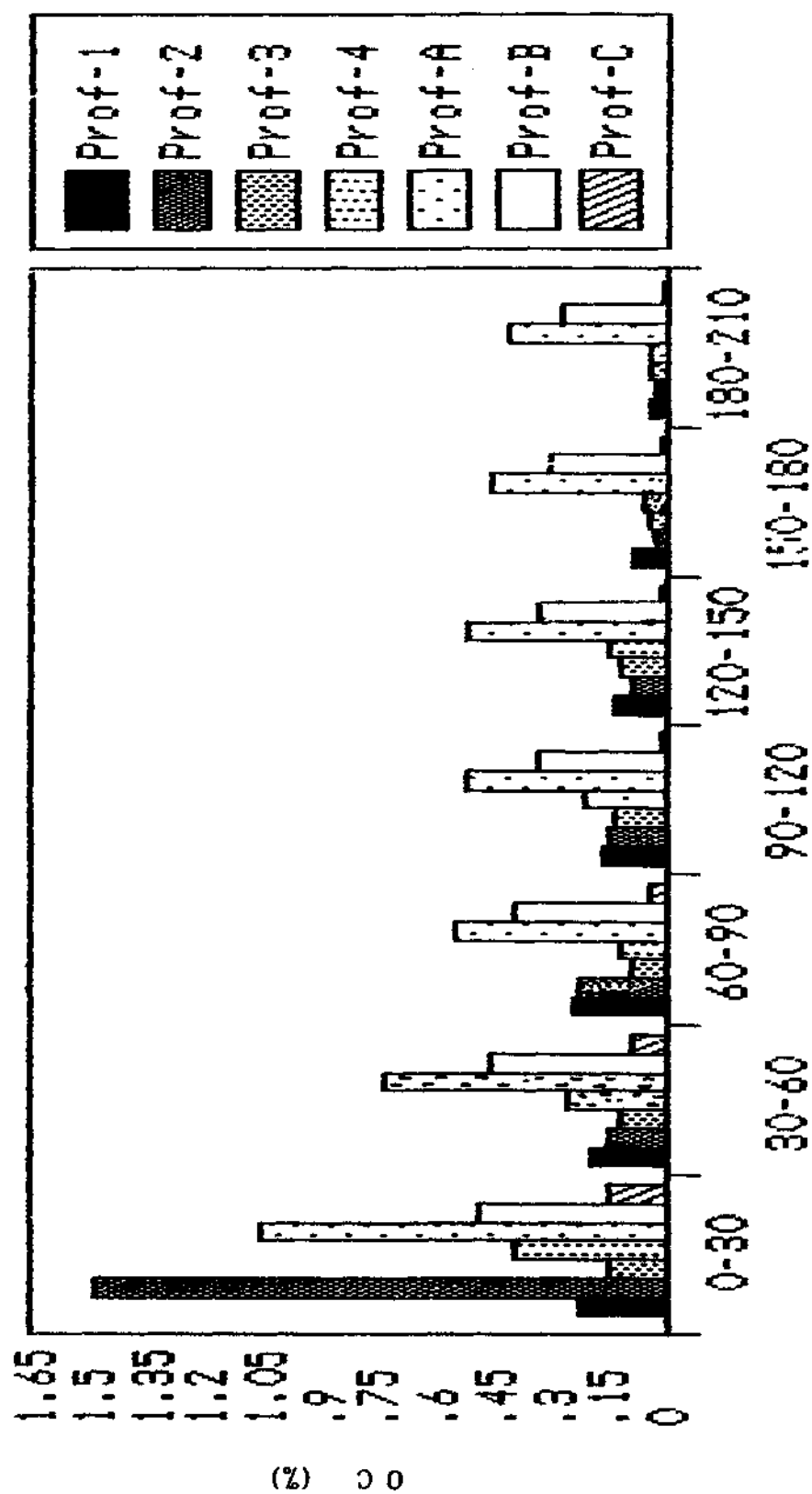


Fig. 5 Organic carbon content of soil profiles influenced by disposal of urban solid wastes at Amberpet landfill site

Table 36 : Chemical characteristics of soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil profiles	Depth (cm)							
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	Mean
Organic Carbon (%)								
Profile-1	0.23	0.20	0.240	0.170	0.140	0.090	0.045	0.150
Profile-2	1.50	0.15	0.230	0.150	0.090	0.030	0.030	0.300
Profile-3	0.15	0.12	0.100	0.140	0.120	0.045	0.045	0.100
Profile-4	0.40	0.27	0.120	0.210	0.150	0.660	0.045	0.180
Profile-A	1.07	0.74	0.550	0.520	0.520	0.460	0.420	0.611
Profile-B	0.49	0.46	0.400	0.340	0.340	0.310	0.280	0.370
Profile-C	0.15	0.09	0.045	0.015	0.011	0.010	0.001	0.047
Free CaCO ₃ (%)								
Profile-1	1.00	2.5	2.0	2.0	3.0	5.0	5.0	2.92
Profile-2	2.00	2.0	3.5	3.5	2.0	3.5	3.5	2.85
Profile-3	2.00	2.0	4.5	4.5	2.0	2.0	9.5	3.78
Profile-4	3.00	9.5	2.5	3.5	3.5	4.0	4.0	4.28
Profile-A	1.30	0.9	0.7	0.6	0.5	0.0	0.0	0.57
Profile-B	1.90	2.1	2.6	2.4	2.3	2.6	2.0	2.28
Profile-C	1.00	1.1	1.2	1.0	1.1	1.2	1.2	1.11
Ca/Mg ratio								
Profile-1	1.66	1.50	1.92	1.15	3.70	2.00	2.50	2.06
Profile-2	1.44	2.14	2.22	4.62	3.30	5.00	1.60	2.90
Profile-3	4.00	2.00	2.30	1.70	1.54	2.00	1.83	2.19
Profile-4	9.00	2.00	1.25	1.80	2.30	1.20	0.81	2.62
Profile-A	0.00	1.40	1.60	2.00	2.00	0.00	0.00	1.00
Profile-B	1.10	1.60	1.30	1.60	2.20	1.30	1.50	1.51
Profile-C	7.00	1.63	1.80	4.00	5.00	6.50	11.00	5.27
Total nitrogen (%)								
Profile-1	0.018	0.017	0.019	0.014	0.011	0.0070	0.0050	0.0130
Profile-2	0.120	0.012	0.018	0.011	0.006	0.0010	0.0010	0.0240
Profile-3	0.120	0.010	0.009	0.011	0.009	0.0020	0.0010	0.0070
Profile-4	0.030	0.017	0.009	0.016	0.011	0.0040	0.0020	0.0120
Profile-A	0.090	0.055	0.004	0.038	0.040	0.0310	0.0200	0.0440
Profile-B	0.032	0.034	0.030	0.031	0.032	0.0290	0.0150	0.0290
Profile-C	0.012	0.007	0.003	0.001	0.001	0.0006	0.0004	0.0036
Exchangeable sodium percentage (E.S.P.)								
Profile-1	7.50	2.65	3.00	3.20	3.47	4.68	8.20	3.63
Profile-2	3.30	1.95	1.20	2.28	4.30	3.80	8.27	2.78
Profile-3	10.80	3.00	3.90	11.78	7.00	5.50	9.40	5.70
Profile-4	3.00	16.80	17.10	14.80	23.90	9.70	6.60	10.21
Profile-A	70.60	46.70	67.00	47.30	42.40	55.30	45.50	41.64
Profile-B	0.55	6.20	2.90	3.10	3.80	3.37	2.90	2.53
Profile-C	0.60	0.49	0.27	1.70	3.20	3.40	4.10	1.52

water as compared to control. The N content decreased with soil depth.

4.3.4 Plant available nutrients

The data are presented in Table 37.

4.3.4.1 Nitrogen: The mean available nitrogen content of all the soil profiles increased over control. It ranged from 7.14 (profile C) to 27.71 ppm (profile A). Among different soil depths the values ranged from 1.0 (180-210 cm) in profile C to 102.0 ppm (0-30 cm) in profile 2 and decreased in general, with soil depth.

4.3.4.2 Phosphorus: The mean available phosphorus content of all the soil profiles increased over control. It ranged from 0.85 (profile 7) to 5.44 ppm (profile 2). Among in soil depths the lowest and highest values ranged from nil (120-210 cm) in profile C to 29.0 ppm (0-30 cm) in profile 2. It decreased as soil depth increased.

4.3.4.3 Potassium: The mean available potassium content of all the soil profiles increased over control. It ranged from 32.42 (profile C) to 4340.0 ppm (profile 4). Among the individual soil depths, it ranged from 21.0 (180-210 cm) in profile C to 8550.0 ppm (90-120 cm) in profile 4 and decreased with increase in soil depth.

Table 37 : Available nutrients in soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil Profiles	Depth (cm)							
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	Mean
	-----ppm-----							
Nitrogen								
Profile-1	30.00	28.00	31.00	22.00	21.00	12.00	7.00	21.57
Profile-2	102.00	20.00	24.00	21.00	11.00	6.00	5.00	27.00
Profile-3	19.00	17.00	14.00	16.00	15.00	6.00	4.00	13.00
Profile-4	49.00	32.00	16.00	26.00	18.00	8.00	6.00	22.14
Profile-A	42.00	35.00	31.00	28.00	29.00	19.00	10.00	27.71
Profile-B	27.00	29.00	26.00	22.00	21.00	18.00	8.00	21.57
Profile-C	22.00	12.00	6.00	4.00	3.00	2.00	1.00	7.14
Phosphorus								
Profile-1	5.00	4.00	5.00	3.00	2.00	1.00	0.50	2.92
Profile-2	29.00	2.00	3.00	2.00	1.00	0.70	0.40	5.44
Profile-3	2.00	1.50	1.20	1.30	1.10	0.60	0.40	1.15
Profile-4	7.00	5.00	1.50	3.00	1.70	0.70	0.30	2.74
Profile-A	6.20	5.10	4.30	3.50	4.00	2.00	1.20	3.75
Profile-B	5.00	4.40	3.00	2.60	1.90	1.00	0.30	2.98
Profile-C	4.00	1.30	0.50	0.20	ND	ND	ND	0.85
Potassium								
Profile-1	5110.00	3182.00	1523.00	776.00	1364.00	571.00	53.00	1797.00
Profile-2	2910.00	816.00	714.00	168.00	102.00	86.00	65.00	694.42
Profile-3	1041.00	755.00	816.00	187.00	104.00	65.00	45.00	430.42
Profile-4	1184.00	3182.00	5386.00	8550.00	5820.00	3318.00	2940.00	4340.00
Profile-A	428.50	1183.60	138.60	147.72	83.67	3650.00	2765.00	808.54
Profile-B	93.87	62.50	42.85	58.90	35.70	39.28	26.00	51.30
Profile-C	39.00	36.00	38.00	38.00	30.00	25.00	21.00	32.42
NH ₄ OAc-Extractable Sodium								
Profile-1	2372.00	1000.00	1151.00	1116.00	607.00	607.00	646.00	1071.28
Profile-2	478.00	147.00	174.00	277.00	309.00	247.00	410.00	291.71
Profile-3	318.00	157.00	444.00	456.00	328.00	161.00	291.00	307.85
Profile-4	314.00	2302.00	4081.00	7200.00	5538.00	3069.00	1674.00	3454.00
Profile-A	3276.90	2584.60	4465.10	3100.00	3000.00	3750.00	2420.00	3228.08
Profile-B	47.50	136.00	249.20	281.50	244.60	244.60	190.00	199.05
Profile-C	10.00	15.00	20.00	24.00	25.00	24.00	23.00	20.14

ND = Not detected.

4.3.4.4 NH_4 OAc - extractable sodium: The mean sodium content of all the soil profiles increased over control. The mean values ranged from 20.14 (profile C) to 3454.0 ppm (profile 4) 4. Among the various soil depths it ranged from 10.0 (0-30 cm) in profile C to 7200.0 ppm (90-120 cm) in profile 4 (Plate 26). The NH_4 OAc extractable Na increased upto 120 cm depth, thereafter decreased as soil depth increased.

4.3.5 Exchangeable sodium percentage (ESP)

The mean exchangeable sodium percentage of all the soil profiles increased over control. It ranged from 1.52 (profile C) to 41.64 (profile A). In soil depths, the ESP values ranged from 0.27 (60-90 cm) in profile C to 70.6 (0-30 cm) in profile A (Fig.6). There was no clear trend to show relationship between in respect of ESP and soil depth. (Table 36).

4.3.6 Water soluble ions

The data are presented in Table 38.

4.3.6.1 Potassium: The mean water soluble potassium content increased in all the profiles, except in profile B over control. It ranged from 4.55 (profile B) to 2992.85 ppm (profile 4). In relation to soil depths, it ranged from 2.5 (180-210 cm) in profile B to 6010.0 ppm (90-120 cm) in profile 4. The soluble K increased to a

certain depth (120 cm) and, thereafter decreased as the soil depth increased.

4.3.6.2 Sodium: The mean water soluble sodium content of all the profiles increased when compared with control. It ranged from 8.0 (profile C) to 3156.14 ppm (profile 4). Among depths, the lowest and highest values recorded ranged from 5.0 (0-30 cm) in profile C to 6750.0 ppm (90-120 cm) in profile 4. It increased to a certain depth (120 cm) and, thereafter, it decreased as soil depth increased.

4.3.6.3 Sulphate: The mean water soluble sulphate content of all the soil profiles increased when compared with control. It ranged from 7.02 (profile C) to 3607.42 ppm (profile 4). At the different soil depths, the lowest and highest values ranged from 4.0 (180-210 cm) in profile C to 7930.0 ppm (90-120 cm) in profile 4 respectively. It increased up to 120 cm depth and thereafter decreased as soil depth increased.

4.3.6.4 Chloride: The mean water soluble chloride content of all the profiles increased over control. It ranged from 3.62 (profile C) to 1703.85 ppm (profile 4). At different depths of soil the, lowest values ranged from 2.5 (180-210 cm) in profile C to 3672.0 ppm (90-120 cm) in profile 4. The chloride content increased to a certain depth (120 cm) and thereafter decreased with increase in depth.

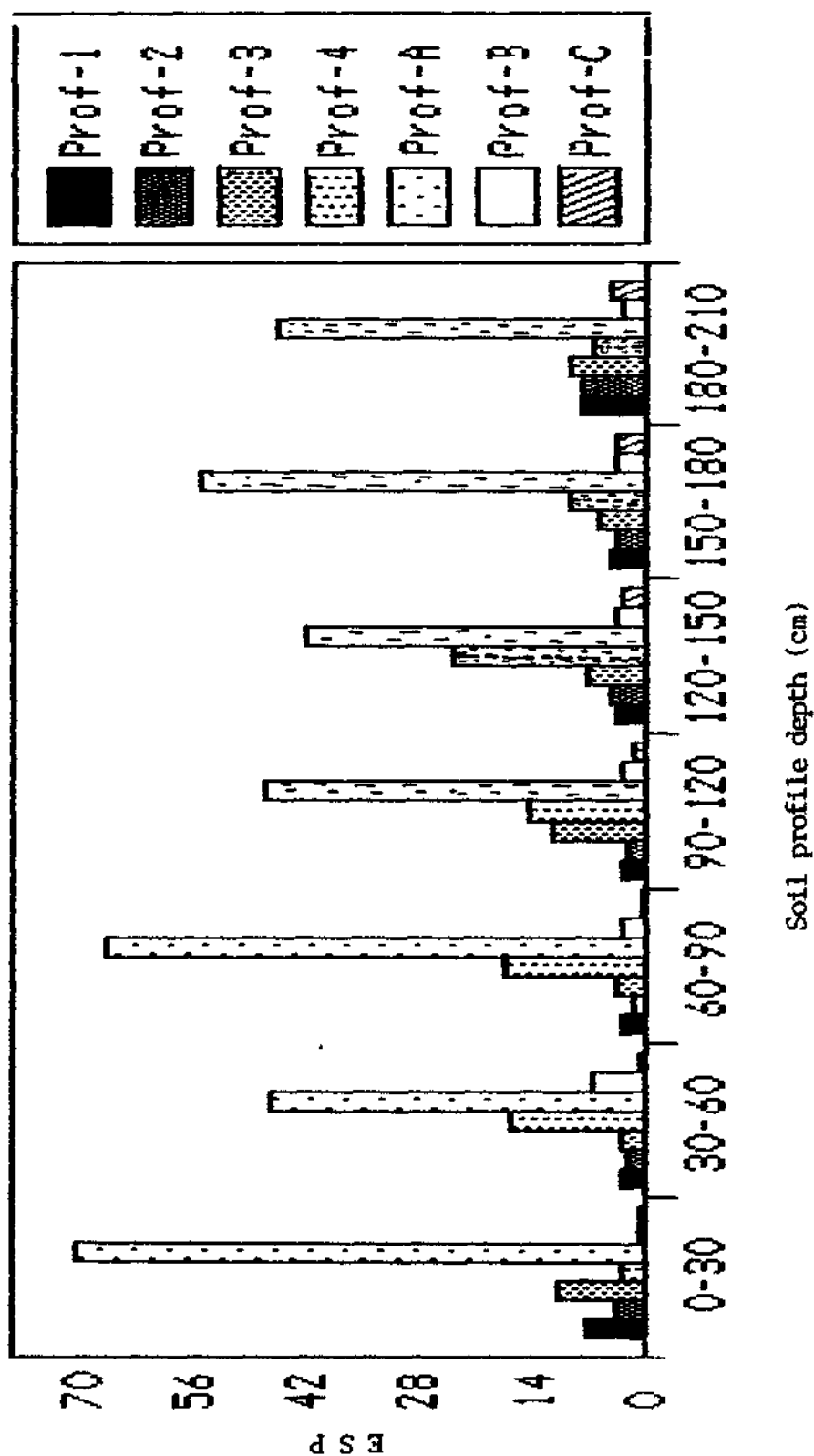


Fig. 6 Exchangeable sodium percentage of soil profiles influenced by disposal of urban solid wastes at Amberpet landfill site

Table 38 : Water soluble ions in soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil profiles	Depth (cm)							
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	Mean
	----- ppm -----							
	Potassium							
Profile-1	2375.00	1500.00	190.00	90.00	210.00	140.00	9.00	644.85
Profile-2	132.50	41.00	39.00	11.00	8.50	7.00	4.90	34.84
Profile-3	82.50	62.00	71.00	18.00	11.00	8.00	7.10	37.08
Profile-4	550.00	1480.00	251.00	6010.00	5010.00	2900.00	2490.00	2992.85
Profile-A	40.00	112.00	13.00	8.00	8.00	2295.00	2000.00	639.42
Profile-B	8.00	6.00	4.00	5.00	3.00	3.40	2.50	4.55
Profile-C	6.30	5.70	6.00	6.10	5.00	4.50	4.00	5.37
	Sodium							
Profile-1	2200.00	930.00	1040.00	1015.00	1510.00	520.00	560.00	1110.71
Profile-2	360.00	109.00	130.00	210.00	230.00	185.00	301.00	217.85
Profile-3	170.00	91.00	260.00	270.00	198.00	99.00	185.00	181.85
Profile-4	263.00	1930.00	3500.00	6750.00	5200.00	2890.00	1560.00	3156.14
Profile-A	1082.00	930.00	1600.00	1025.00	1000.00	2650.00	2010.00	1471.00
Profile-B	38.00	13.00	176.00	201.00	160.00	176.00	150.00	130.57
Profile-C	5.00	6.00	10.00	11.00	9.00	8.50	6.50	8.00
	Sulphate							
Profile-1	2354.00	1462.00	646.00	521.00	1010.00	218.00	200.00	915.85
Profile-2	212.00	75.00	77.00	102.00	164.00	123.00	148.00	128.71
Profile-3	122.00	83.00	185.00	169.00	114.00	56.00	108.00	119.57
Profile-4	411.00	1916.00	3274.00	7930.00	6024.00	3024.00	2673.00	3607.42
Profile-A	750.00	610.00	1200.00	725.00	680.00	3117.00	540.00	1089.85
Profile-B	21.00	10.00	110.00	125.00	110.00	109.00	95.00	82.85
Profile-C	7.10	6.90	10.20	9.50	6.00	5.50	4.00	7.02
	Chloride							
Profile-1	1431.00	524.00	273.00	296.00	369.00	214.00	180.00	469.57
Profile-2	121.00	25.00	32.00	41.00	12.00	20.00	54.00	43.57
Profile-3	31.00	26.00	67.00	51.00	25.00	23.00	42.00	37.85
Profile-4	154.00	671.00	1714.00	3672.00	2981.00	1873.00	862.00	1703.85
Profile-A	234.00	190.00	344.00	255.00	210.00	1364.00	130.00	389.57
Profile-B	7.40	4.30	30.00	62.00	34.00	36.00	28.00	28.81
Profile-C	3.20	3.00	4.20	5.30	4.00	3.20	2.50	3.62

ND = Not detected.



Depth (cm)	Water soluble ions (ppm)				ESP	Available (ppm)			NH ₄ OAC extractable		O.C. %
	K ⁺	Na ⁺	SO ₄ ⁼	Cl ⁻		N	P	K	Na		
										(ppm)	
Waste	180-210	1250-1870	740-1269	1110-1931	324- 640	--	98-104	28.0-30.0	2400-2800	837-1395	1.44-1.56
Soil pro- file	0- 30	82.5-2375	170-2200	122-2354	31-1431	3.00-10.8	19-102	2.0-29.0	1041-5110	314-2372	0.15-1.50
	30- 60	41-1500	91-1930	75-1916	25- 671	1.95-16.5	17- 32	1.5- 5.0	755-3182	147-2302	0.12-0.27
	60- 90	39- 251	130-3500	77-3274	32-1714	1.20-17.1	14- 31	1.2- 5.0	714-5386	174-4081	0.10-0.24
	90-120	11-6010	210-6750	102-7930	41-3672	2.28-14.8	16- 26	1.3- 3.0	187-8550	277-7200	0.14-0.21
	120-150	8.5-5010	198-5200	114-6024	12-2981	3.47-23.9	11- 21	1.0- 2.0	102-5820	309-5538	0.09-0.15
	150-180	7-2900	99-2890	56-3024	20-1873	3.80- 9.7	8- 12	0.6- 1.0	65-3318	161-3068	0.03-0.09
	180-210	4.9-2490	185-1560	108-2673	42- 862	6.60- 9.4	4- 7	0.3- 0.5	45-2940	291-1674	0.03-0.04

Plate 26 : Soil profile (1 to 4) characteristics (range)
under urban solid wastes at Amberpet landfill site-
chemical properties

4.3.7 Total micronutrients

The data pertaining to total micronutrients contents in soil profiles are presented in Table 39.

4.3.7.1 Iron: The mean total iron content of all the soil profiles decreased over control. It ranged from 8425.7 (profile A) to 13737.88 ppm (profile C). At different soil depths, the values ranged from 5707.8 (0-30 cm) in profile 3 to 15374.5 (120-150 cm) ppm in profile 2.

4.3.7.2 Manganese: The mean manganese content of all the soil profiles decreased as compared to control. It ranged from 220.0 (profile 1) to 501.85 ppm (profile C). At the different soil depths, the values ranged from 20.0 (0-30 cm) in profile 3 to 760.0 ppm (180-210 cm) in profile C. In general, it increased as soil depth increased.

4.3.7.3 Zinc: The mean zinc content of all the soil profiles decreased when compared with control. It ranged from 17.84 (profile A) to 84.57 (profile C) ppm. At different soil depths, the values ranged from 12.0 (180-210 cm) in profile A to 136.9 ppm (120-150 cm) in profile 2. In general it increased with increase in soil depth.

4.3.7.4 Copper: The mean copper content of all the soil profiles, except two (profiles A and B) increased when compared with control. It ranged from 8.75 (profile A)

Table 39 : Total micronutrient concentration in soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil Profile	Depth (cm)							
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	Mean
	----- ppm -----							
	Iron							
Profile-1	9798.70	9283.60	12647.20	13340.00	11859.00	11283.60	13647.20	11694.18
Profile-2	13192.70	9010.90	14404.80	13980.60	15374.50	13313.90	13950.30	13318.24
Profile-3	5707.80	8010.90	13677.60	12768.40	12738.10	12768.40	15313.90	11569.29
Profile-4	8586.00	10586.00	14707.80	15192.70	14132.10	15010.90	12920.00	13019.35
Profile-A	6950.00	6283.60	8677.50	8768.40	10192.70	9465.40	8642.50	8425.72
Profile-B	9223.00	9101.80	11404.80	9526.00	10526.00	9192.70	8972.00	9706.61
Profile-C	14738.10	15210.00	14785.00	14132.10	13250.10	12050.00	12000.00	13737.88
	Manganese							
Profile-1	60.00	60.00	240.00	60.00	280.00	320.00	520.00	
Profile-2	320.00	110.00	700.00	520.00	580.00	590.00	390.00	
Profile-3	20.00	70.00	500.00	390.00	380.00	180.00	370.00	
Profile-4	110.00	150.00	320.00	280.00	290.00	490.00	400.00	
Profile-A	330.00	200.00	410.00	440.00	500.00	490.00	380.00	
Profile-B	410.00	310.00	240.00	210.00	310.00	200.00		
Profile-C	150.00	261.00	422.00	590.00	620.00	710.00		
	Zinc							
Profile-1	37.90	30.00	37.00	35.90	36.40	70.90	114.10	51.74
Profile-2	85.80	23.60	42.70	50.80	136.90	103.90	113.90	82.51
Profile-3	31.50	29.60	41.90	45.60	76.90	71.30	101.40	56.88
Profile-4	57.30	80.70	68.00	56.60	57.90	68.30	64.00	64.68
Profile-A	22.00	12.70	22.20	21.90	18.10	16.00	12.00	17.84
Profile-B	57.90	25.50	13.20	15.30	17.70	22.10	19.00	24.38
Profile-C	41.40	54.20	72.30	99.10	100.00	110.10	115.00	84.57
	Copper							
Profile-1	11.70	8.40	15.90	19.00	11.70	5.30	5.20	11.02
Profile-2	30.20	29.90	18.00	18.00	18.60	14.90	13.80	20.48
Profile-3	14.50	10.30	15.10	14.10	12.50	10.00	15.50	13.14
Profile-4	19.10	32.60	26.20	21.20	17.30	11.80	7.00	19.31
Profile-A	9.40	6.10	9.50	8.90	10.30	9.60	7.50	8.75
Profile-B	20.50	11.50	8.70	7.40	7.50	6.20	4.50	9.47
Profile-C	13.40	12.60	11.10	10.50	9.00	8.20	7.30	10.30

=====

to 20.48 (profile 2) ppm. In relation to its distribution with soil depth, the values ranged from 4.5 (180-210 cm) in profile B to 32.6 ppm (30-60 cm) in profile 4. In general, the copper content of soils decreased with increase in soil depth, which is contrary to the pattern of distribution of manganese and zinc in soil at different depths.

The total micronutrient contents in soil profiles followed the order of $\text{Fe} > \text{Mn} > \text{Zn} > \text{Cu}$.

4.3.8 Total heavy metals

The data are presented in Table 40.

4.3.8.1 Lead: The mean lead content of all the soil profiles increased when compared with control. It ranged from 3.58 (profile C) to 96.71 ppm (profile 2). Studies on depthwise distribution of lead indicate that the values ranged from 2.1 (180-210 cm) in profile C to 126.0 (120-150 cm) ppm in profile 2 respectively. The distribution of lead increase or decrease in soil did not follow any specific pattern with change in depth of soil.

4.3.8.2 Nickel: The mean nickel content of soil profiles ranged from 6.35 (profile B) to 25.51 ppm (profile 4). In contrast it decreased in profiles A and B. In relation to soil depths, the values ranged from 0.8 (0-

30 cm) in profile 3 to 45.6 ppm (90-120 cm) in profile 4 (Plate-27). No clear trend of increase or decrease with soil depth was obtained.

4.3.8.3 Cobalt: The mean cobalt content of all the soil profiles decreased when compared with control. It ranged from 2.87 (profile B) to 10.58 (profile C) ppm. At different soil depths, the lowest and highest contents of cobalt ranged from 1.0 (150-180 cm) in profile B to 14.0 (180-210 cm) ppm in profile 1. No specific trend in depthwise distribution of this element was observed.

4.3.8.4 Cadmium: The mean cadmium content of soil profiles ranged from 0.011 (profile 2 and C) to 1.08 (profile B) ppm. In relation to soil depth, the lowest and highest values were 0.01 and 2.0 ppm respectively and did not show any clear trend with change in soil depths.

4.3.8.5 Chromium: The mean chromium content of soil profiles ranged from 4.25 (profile 1) to 23.85 (profile A) ppm. Among different soil depths the lowest and highest contents were 1.1 (0-30 cm) in profile 1 and 67.0 (0-30 cm) ppm in profile A, respectively.

In general, the concentration of heavy metals in soil profiles followed the order of $Pb > Ni > Co > Cr > Cd$ eventhough Pb, Ni, Cr and Cd increased and Co decreased when compared with control profile.

Table 40: Total heavy metal concentration in soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil profiles	Depth (cm)							
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	Mean
	-----ppm-----							
	Lead							
Profile-1	34.00	30.00	64.00	38.00	82.00	72.00	60.00	54.28
Profile-2	99.00	91.00	63.00	81.00	126.00	123.00	94.00	96.71
Profile-3	49.00	47.00	73.00	79.00	28.00	14.00	52.00	48.85
Profile-4	23.00	55.00	42.00	73.00	43.00	18.00	50.00	43.42
Profile-A	30.00	6.00	14.00	39.00	15.00	29.00	19.00	21.71
Profile-B	30.00	30.00	39.00	5.00	27.20	36.67	10.50	25.48
Profile-C	6.50	5.40	4.20	2.30	2.40	2.20	2.10	3.58
	Nickel							
Profile-1	6.20	8.20	25.70	16.40	14.50	12.20	21.50	14.95
Profile-2	14.70	5.30	23.10	14.00	16.60	9.20	14.80	13.95
Profile-3	1.80	7.30	14.60	16.40	8.90	7.90	19.20	10.87
Profile-4	10.70	14.80	33.90	45.60	30.20	24.90	18.50	25.51
Profile-A	8.20	5.50	7.80	8.70	9.40	12.30	8.50	8.62
Profile-B	10.70	6.40	2.80	4.70	5.10	8.30	6.50	6.35
Profile-C	13.00	14.20	15.30	16.70	14.00	10.50	9.00	13.24
	Cobalt							
Profile-1	5.00	11.00	11.00	3.00	8.00	9.00	14.00	8.71
Profile-2	12.00	3.00	11.00	12.00	13.00	9.00	8.40	9.77
Profile-3	1.00	4.60	11.00	7.00	6.00	8.00	11.00	6.94
Profile-4	2.90	5.70	12.00	11.00	8.00	11.00	7.00	8.22
Profile-A	3.00	5.00	8.00	4.00	9.00	7.00	6.00	6.00
Profile-B	5.00	2.00	6.00	2.00	3.00	1.00	1.10	2.87
Profile-C	7.00	8.20	10.00	11.70	12.00	12.40	12.80	10.58
	Cadmium							
Profile-1	0.020	0.010	0.025	0.010	0.022	0.010	0.010	0.015
Profile-2	0.010	0.010	0.020	0.010	0.011	0.012	0.010	0.011
Profile-3	0.014	0.016	0.011	0.012	0.013	0.018	0.012	0.012
Profile-4	0.014	0.017	0.025	0.012	0.024	0.010	0.014	0.011
Profile-A	0.500	1.000	0.500	2.000	1.000	1.000	1.000	1.000
Profile-B	0.400	0.500	1.000	0.500	2.000	2.000	1.200	1.080
Profile-C	0.012	0.014	0.011	0.010	0.010	0.010	0.010	0.011
	Chromium							
Profile-1	1.10	3.20	5.70	5.00	3.00	5.00	6.80	4.25
Profile-2	5.50	5.00	6.00	5.60	5.20	5.00	5.00	5.32
Profile-3	4.80	5.00	6.50	8.20	4.80	9.70	2.40	5.91
Profile-4	7.30	2.90	4.30	8.00	6.50	4.00	4.50	5.35
Profile-A	67.00	10.50	8.50	10.20	40.00	18.80	12.00	23.85
Profile-B	18.20	1.60	2.90	2.60	12.00	2.30	2.50	6.05
Profile-C	7.50	6.10	5.00	4.80	3.40	2.80	2.20	4.54

Depth (cm)	Total trace elements (ppm)								
	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	Cr
Waste 180-210	5526- 9253	250-680	152.4-359.1	63.0-134.0	66.4-186.8	12.0-24.2	5.0- 7.0	1.000-2.000	19.0-73.0
Soil pro- file	0- 30	20-320	31.5- 85.8	11.7- 30.2	23.0- 99.0	1.8-14.7	1.0-12.0	0.010-0.020	1.1- 7.3
	30- 60	60-150	23.6- 80.7	8.4- 32.6	30.0- 91.0	5.3-14.8	3.0-11.0	0.010-0.017	2.9- 5.0
	60- 90	240-700	37.0- 68.0	15.1- 26.2	42.0- 73.0	14.6-33.9	11.0-12.0	0.011-0.025	4.3- 6.5
90-120	12768-15193	60-520	35.9- 56.6	14.1- 21.2	38.0- 81.0	14.0-45.6	3.0-12.0	0.010-0.012	5.0- 8.2
120-150	11859-15374	280-580	36.4-136.9	11.7- 18.6	28.0-126.0	8.9-30.2	6.0-13.0	0.011-0.024	3.0- 6.5
150-180	11284-15011	180-590	70.9-103.9	5.3- 14.9	14.0-123.0	7.9-24.9	8.0-11.0	0.010-0.018	4.0- 9.7
180-210	12920-15314	370-520	64.0-114.1	5.2- 15.5	15.0- 94.0	14.8-21.5	7.0-14.0	0.010-0.140	2.4- 6.8

Plate 27 : Soil profile (1 to 4) characteristics (range)
under urban solid wastes at Amberpet landfill site-
total trace elements content



4.3.9 DTPA-extractable micronutrients

The data are presented in Table 41.

4.3.9.1 Iron: The mean iron content in soil profiles ranged from 7.25 (profile B) to 16.35 (profile 4) ppm and were not very much different in the concentration of iron extracted from DTPA in control. In soil depths the lowest and highest contents ranged from 4.0 (180-210 cm) in profile B and C and 38.6 ppm (150-180 cm) in profile A) respectively and in general decreased with the increase in soil depth.

4.3.9.2 Manganese: The mean manganese content of all the soil profiles increased over control. It ranged from 5.71 (profile C) to 18.91 (profile 4) ppm. The soil depthwise distribution of manganese showed that the lowest and highest values of 1.6 (180-210 cm) in profile C and 41.42 ppm (0-30 cm) in profile B respectively and did not show any specific trend with change in soil depth.

4.3.9.3 Zinc: The mean zinc content of all the soil profiles increased except in profile 1. It ranged from 1.03 (profile 1) to 2.87 (profile 4) ppm. The depth-wise distribution of zinc showed that the lowest and highest Zn contents were 0.5 (180-210 cm) in profile C and 11.2 ppm (0-30 cm) in profile B respectively. In

Table 41 : DTPA-extractable micronutrient concentration in soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil profiles	Depth (cm)							
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	Mean
	-----ppm-----							
	Iron							
Profile-1	23.70	20.10	10.00	6.25	6.70	5.40	6.30	11.20
Profile-2	22.00	15.30	9.60	10.30	10.70	11.30	10.00	12.74
Profile-3	22.00	22.00	7.00	6.50	7.50	7.30	7.50	11.40
Profile-4	24.20	31.60	20.30	8.70	8.50	11.60	9.60	16.37
Profile-A	16.60	14.50	9.90	8.80	9.80	38.60	11.50	15.67
Profile-B	20.20	9.00	4.90	4.40	4.20	4.50	4.00	7.25
Profile-C	17.80	14.10	12.40	11.80	8.00	6.50	4.00	10.65
	Manganese							
Profile-1	3.20	2.60	12.70	13.80	8.50	8.50	5.00	7.75
Profile-2	8.52	2.74	12.30	10.56	7.68	7.04	5.52	7.76
Profile-3	4.50	4.80	20.50	9.82	6.10	2.80	3.70	7.46
Profile-4	4.74	6.79	18.60	36.80	29.90	18.90	16.70	18.91
Profile-A	8.92	5.52	4.60	4.40	6.80	17.20	9.50	8.13
Profile-B	41.42	25.26	15.20	10.60	5.50	4.80	4.10	15.26
Profile-C	9.20	8.60	7.40	6.70	4.00	2.50	1.60	5.71
	Zinc							
Profile-1	1.56	1.39	0.96	0.92	0.91	0.91	0.58	1.03
Profile-2	3.40	0.88	0.90	1.32	1.96	1.77	1.31	1.64
Profile-3	2.60	1.50	1.60	2.40	3.30	2.50	1.40	2.18
Profile-4	3.90	6.60	2.20	1.90	1.80	1.70	2.00	2.87
Profile-A	1.66	1.47	1.40	1.70	1.14	1.70	1.40	1.49
Profile-B	11.20	4.40	1.00	0.70	0.80	1.90	0.70	2.81
Profile-C	2.30	1.80	1.50	1.30	0.90	0.70	0.50	1.28
	Copper							
Profile-1	2.34	1.90	2.20	1.60	1.60	0.97	0.68	1.61
Profile-2	4.20	1.80	2.00	2.20	1.40	1.40	0.97	1.99
Profile-3	4.65	2.35	2.30	1.95	1.50	1.20	1.10	2.15
Profile-4	6.40	11.90	3.95	2.80	2.80	1.95	1.56	4.48
Profile-A	3.00	1.78	1.68	1.58	1.87	2.40	2.00	2.04
Profile-B	8.00	4.00	1.60	1.20	0.90	1.70	1.20	2.65
Profile-C	2.80	1.25	0.80	0.60	0.40	0.20	0.10	0.87

general, the Zn content decreased with increase in soil depth.

4.3.9.4 Copper: The mean copper content of all the soil profiles increased when compared with control. It ranged from 0.87 (profile C) to 4.48 ppm (profile 4) (Plate-28). The distribution of copper in relation to soil depth indicated that the values ranged from 0.1 (180-210 cm) in profile C to 11.9 (30-60 cm) ppm in profile 4. It decreased as soil depth increased.

The content of DTPA-micronutrients in soil profiles followed the order $Mn > Fe > Cu > Zn$ and they showed increased over control.

4.3.10 DTPA-extractable heavy metals

The data are presented in Table 42.

4.3.10.1 Lead: The mean lead content of all the soil profiles increased over control, It ranged from 0.05 (profile C) to 1.78 (profile 4). Among different soil depths, the values ranged from nil (150-210 cm) in profile C to 3.7 ppm (30-60 cm) in profile 4. It did not show any clear trend with change in soil depth.

4.3.10.2 Nickel: The mean nickel content of all the soil profiles increased over control. It ranged from 0.07 (profile C) to 0.77 ppm (profile B). As for the distribution of nickle with soil depth, the values ranged from

Table 42 : DTPA-extractable heavy metals concentration in soil profiles under urban solid wastes at Amberpet landfill site, Hyderabad city

Soil profiles	Depth (cm)							
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	Mean
	-----ppm-----							
	Lead							
Profile-1	1.60	1.70	0.80	1.500	0.500	0.50	1.00	1.08
Profile-2	1.00	1.80	0.10	1.100	1.700	3.40	1.70	1.54
Profile-3	0.78	0.41	0.80	1.000	0.500	0.14	0.29	0.56
Profile-4	1.20	3.70	2.10	2.400	1.800	0.78	0.53	1.78
Profile-A	1.50	0.88	1.06	1.040	1.550	3.11	2.00	1.59
Profile-B	1.90	0.51	0.08	0.010	0.020	0.02	0.01	0.36
Profile-C	0.14	0.13	0.12	0.001	0.001	ND	ND	0.05
	Nickel							
Profile-1	0.57	0.15	0.23	0.350	0.220	0.14	0.01	0.23
Profile-2	0.41	0.26	0.32	0.310	0.090	0.16	0.14	0.24
Profile-3	0.29	0.34	0.47	0.340	0.140	0.08	0.17	0.26
Profile-4	0.35	0.60	0.63	1.000	0.740	0.50	0.37	0.60
Profile-A	0.25	0.33	0.29	0.270	0.380	1.04	0.40	0.42
Profile-B	2.53	1.24	0.46	0.304	0.364	0.32	0.21	0.77
Profile-C	0.24	0.18	0.09	0.001	0.001	ND	ND	0.07
	Cobalt							
Profile-1	1.38	1.80	0.33	2.70	1.81	1.58	2.20	1.68
Profile-2	0.67	1.26	1.58	0.82	0.66	0.14	2.30	1.06
Profile-3	0.52	1.07	3.01	1.45	2.10	1.23	0.80	1.45
Profile-4	1.55	2.46	4.27	0.17	7.90	2.11	0.55	2.71
Profile-A	0.56	2.30	2.50	1.40	1.70	2.00	1.80	1.75
Profile-B	0.92	0.14	0.40	0.82	2.10	0.66	0.42	0.78
Profile-C	0.40	0.38	0.31	0.24	0.10	ND	ND	0.20

ND = Not detected



DTPA-Extractable trace elements (ppm)

Depth (cm)	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	Cr
Waste 180-210	52.00-57.0	12.00-18.40	22.00-61.0	31.20-36.40	14.40-34.0	0.40-1.44	1.41-3.00	ND	ND
Soil 0-30	22.00-24.0	3.20-8.52	1.56-3.9	2.34-6.40	0.78-1.6	0.29-0.57	0.52-1.55	ND	ND
30-60	15.30-31.6	2.60-6.29	0.88-6.6	1.80-11.90	0.41-3.7	0.15-0.60	1.07-2.46	ND	ND
60-90	7.00-20.3	12.30-20.50	0.90-2.2	2.00-3.95	0.10-2.1	0.23-0.63	0.33-4.27	ND	ND
90-120	6.25-10.3	9.82-36.80	0.92-2.4	1.60-2.80	1.00-2.4	0.31-1.00	0.17-2.70	ND	ND
120-150	6.70-10.7	6.10-29.90	0.91-3.3	1.40-2.80	0.50-1.8	0.09-0.74	0.66-7.90	ND	ND
150-180	5.40-11.6	2.80-18.90	0.91-2.5	0.97-1.95	0.14-3.4	0.08-0.50	0.14-2.10	ND	ND
180-210	6.30-10.0	3.70-16.70	0.58-2.0	0.68-1.56	0.29-1.7	0.01-0.37	0.55-2.30	ND	ND

Plate 28 : Soil profile (1 to 4) characteristics (range)
under urban solid wastes at Amberpet landfill site-
DTPA - extractable trace elements content

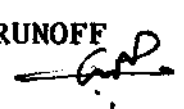
nil (150-210 cm) in profile C to 12.3 (150-180 cm) ppm in profile A and, in general, decreased with increase in soil depth.

4.3.10.3 Cobalt: The mean cobalt content of all the soil profiles increased over control. It ranged from 0.20 (profile C) to 2.71 (profile 4) ppm. Among different depths, the contents ranged from nil (150-210 cm) in profile C to 7.9 (120-150 cm) ppm in profile 4. It did not show any trend with soil depth.

4.3.10.4 Cadmium and Chromium: The cadmium and chromium content could not be detected at any depth in the soil profiles including control.

In general, the concentration of DTPA-extractable heavy metals in soil profiles followed the order of $Pb > Co > Ni > Cr = Cd$, where Pb, Co and Ni contents increased in all the profiles, Cr and Cd contents could not be detected in soils.

4.4 ACCUMULATION OF PLANT GROWTH INHIBITORS IN SOIL DUE TO DISPOSAL OF URBAN SOLID WASTES OR RUNOFF WATER



In any environment impact assessment study involving use of land for waste disposal, it is necessary to identify a simple procedure to assess the impact so as to enable one to recommend combative, reclamative or preventive measures. With this in view the efficiency

of a simple method of bioassay using crop species was tested.

The details of the procedure tested was given in Section 3.2.

The seeds of different crops germinated poorly and growth of seedlings was also affected in soil samples of all depths obtained from profile-4. Setaria italica, however, germinated in all the soil samples, except at 60-90 and 90-120 cm depths very well. From this initial screening, it was understood that Setaria italica can be preferentially employed as a test plant for conducting a rapid bioassay as it is tolerant to salinity.

The results obtained on the growth of Setaria in different soil profiles are presented in Table 43. As is evident, the seeds germinated in all the soil profiles and exhibited variable growth except in profile A and in soil depths 60-90 and 90-120 cm of profile 4. The germination of Setaria in soil samples obtained from different depths in control profile (C) was, however, normal. The growth of Setaria seedlings differed also with depth of the soil. This procedure is therefore, effective in identifying the accumulation of seed germination and plant growth inhibiting or promoting factors in soils. It enables location of the soil depth where

such germination and growth inhibiting or promoting factors accumulated due to downward movement of leachate through the soil profile.

4.4.1 Dry matter yield of Italian millet (Setaria italica)

The dry matter yields weight of Setaria italica seedlings after harvest at 15 DAS are presented in Table 43.

In general, the mean dry matter yields of the Italian millet seedlings increased in all the profiles except in profile-1 as compared to control. In some of the depths of the soil profile, the increase in dry matter yield of the seedlings was more ex: 30-60 cm of profile 2 - 1255.0 mg dish⁻¹. The mean increase in dry matter yield in all the soil profiles ranged from 245.28 (profile 1) to 471.28 mg/dish (profile 3). Among soil depths, the lowest and highest dry matter yields, of seedlings were 30 (150-180 cm) in profile 1 and 1255.0 mg dish⁻¹ (30-60 cm) in profile 2 respectively.

In soil profile A (at all depths) and soil profile 4 (60-90 and 90-120 cm depths) no dry matter yields could not be recorded as there was no germination of seeds in these soils.

Table 43: Dry matter yield of Italian millet (*Setaria italica* L.) grown on soil profile samples collected from Amberpet landfill site, Hyderabad city

Profile	Depth (cm)								Mean
	0-30	30-60	60-90	90-120	120-150	150-180	180-210		
	mg dish ⁻¹								
Profile 1	193	178	118	656	77	30	465	245.28	
Profile 2	586	1255	181	271	170	610	101	453.42	
Profile 3	950	486	295	394	350	435	389	471.28	
Profile 4	1062	662	NG	NG	450	185	202	365.85	
Profile B	700	113	537	314	307	76	65	301.71	
Profile C	400	315	262	203	215	195	170	251.42	

NG - Not germinated.

4.5 IMPACT OF URBAN SOLID WASTE DISPOSAL ON GROUND AND SURFACE WATER QUALITY AT AMBERPET AND GOLKONDA LANDFILL SITES

4.5.1 Characteristics of runoff water

The landfill site located at Amberpet has two large water bodies where the runoff from the landfill which is located at a higher elevation, collects. There is the distinct possibility of this water being used for drinking by cattle and may also be used for cleaning cattle, domestic cooking vessels or washing cloths. It is, therefore, necessary to analyse the water for various parameters so as to enable the use of the criteria for determining the water quality. The data on analysis of runoff water are presented in Tables 44 and 45.

4.5.1.1 Physico-chemical properties

The data are presented in Table 44.

pH: The pH of water samples ranged from 8.3 to 8.8 with a mean of 8.5 showing that they are alkaline in nature. It did not show any specific trend with the distance from landfill site.

Temperature: The temperature of runoff water samples ranged from 20.0 to 22.5°C with a mean of 21.53.

Electrical conductivity: The electrical conductivity of runoff waters ranged from 0.15 to 0.186 d S m⁻¹ with a mean of 0.17.

Turbidity: The turbidity of runoff waters ranged from 1.4 to 2.1 NTU with a mean of 1.68.

Dissolved carbon dioxide: The dissolved CO_2 content of runoff waters ranged from 0.30 to 0.72 mg l^{-1} with a mean of 0.48.

Total solids: The total solids of runoff waters ranged from 147.0 to 181.0 mg l^{-1} with a mean of 165.41.

Total dissolved solids: The total dissolved solids of runoff waters ranged from 110.4 to 145.4 mg l^{-1} with a mean of 129.48.

Total suspended solids: The total suspended solids of runoff waters ranged from 30.9 to 48.6 mg l^{-1} with a mean of 35.93.

Total Hardness: The hardness of runoff waters ranged from 45.5 to 57.8 mg l^{-1} with a mean of 49.95.

Ca - Hardness: The Ca hardness (as CaCO_3) of runoff waters ranged from 27.6 to 42.1 mg l^{-1} with a mean of 23.3.

Mg-Hardness: The Mg-hardness (as CaCO_3) of runoff waters ranged from 13.3 to 23.9 mg l^{-1} with a mean of 16.65.

Dissolved oxygen: The dissolved oxygen of runoff waters ranged from 6.9 to 7.2 mg l^{-1} with a mean of 7.08.

Table 44 : Physico-chemical characteristics of runoff water collected from Amberpet landfill site, Hyderabad city

Sample Distance		pH	Temp. °C	E.C. -1 d Sm	Turbidity (NTU)	Dissolved CO ₂	Total solids	Total	
No.	from landfill site (m)							dissolved solids	suspended solids
1.	10	8.8	22.5	0.186	2.10	0.72	181.0	145.4	35.6
2.	15	8.6	22.0	0.172	1.60	0.63	168.0	119.4	48.6
3.	20	8.5	21.0	0.180	2.00	0.51	178.0	141.7	36.3
4.	25	8.4	20.0	0.164	1.50	0.44	157.5	126.6	30.9
5.	30	8.3	22.2	0.150	1.40	0.31	147.0	110.4	36.6
6.	35	8.4	21.5	0.168	1.52	0.30	161.0	133.4	27.6
Mean	--	8.5	21.53	0.170	1.68	0.48	165.41	129.48	35.93
Range	--	8.3 to 8.8	20.0 to 22.5	0.15 to 0.186	1.4 to 2.1	0.30 to 0.72	147.0 to 181.0	110.0 to 145.4	30.9 to 48.6

Sample No.	Distance from landfill site (m)	Ca-hardness as CaCO_3 (mg l^{-1})			Dissolved oxygen	Carbonate hardness as CaCO_3 (mg l^{-1})	Non-Alkaline hardness	Total Alkalinity	P-Alkalinity	MO-Alkalinity
		Total hardness as CaCO_3	Mg-hardness as CaCO_3	Ca-hardness as CaCO_3						
1.	10	57.8	42.1	15.7	7.0	57.8	Nil	22.4	2.1	20.3
2.	15	49.0	33.5	15.5	6.9	49.0	Nil	15.3	1.8	13.5
3.	20	51.5	27.6	23.9	7.1	51.5	Nil	20.6	2.2	18.4
4.	25	47.5	31.4	16.1	7.2	47.5	Nil	14.0	1.6	12.4
5.	30	45.5	32.2	13.3	7.1	45.5	Nil	13.1	1.3	11.8
6.	35	48.4	33.0	15.4	7.2	48.4	Nil	14.8	1.5	13.3
Mean	--	49.95	33.3	16.65	7.08	49.95	Nil	16.7	1.75	14.95
Range	--	45.5 to 57.8	27.6 to 42.1	13.3 to 23.9	6.9 to 7.2	45.5 to 57.8	Nil	13.1 to 22.4	1.3 to 2.2	11.8 to 20.3

Carbonate hardness: The carbonate hardness of runoff waters is similar to that of total hardness.

Non-alkalinity hardness: The non-alkalinity hardness of runoff waters was found to be nil.

Total alkalinity: The total alkalinity of runoff waters ranged from 13.1 to 22.4 mg l⁻¹ with a mean of 16.70.

P-Alkalinity: The P-alkalinity of runoff waters ranged from 1.30 to 2.2 mg l⁻¹ with a mean of 1.75.

Mo-Alkalinity: The Mo-alkalinity of runoff waters ranged from 11.8 to 20.3 mg l⁻¹ with a mean of 14.95.

4.5.1.2 Chemical properties

The data are presented in Table 45.

Biochemical oxygen demand: The B.O.D. of runoff waters ranged from 1.2 to 1.6 mg l⁻¹ with a mean of 1.35.

Chemical oxygen demand: The C.O.D. of runoff waters ranged from 2.0 to 2.3 mg l⁻¹ with a mean of 2.08.

Potassium: The potassium content of runoff waters ranged from 0.85 to 1.2 mg l⁻¹ with a mean of 0.97.

Sodium: The sodium content of runoff waters ranged from 9.8 to 16.5 mg l⁻¹ with a mean of 11.71.

Chloride: The chloride content of runoff waters ranged from 7.8 to 11.4 mg l⁻¹ with a mean of 9.16.

Sulphate: The sulphate content of runoff waters ranged from 0.86 to 2.5 mg l⁻¹ with a mean of 1.38.

Phosphate: The phosphate content of runoff waters ranged from 0.16 to 0.23 mg l⁻¹ with a mean of 0.18.

Boron: The boron content of runoff waters ranged from 0.14 to 0.21 mg l⁻¹ with a mean of 0.17.

Carbonate: The carbonate content of runoff waters ranged from 2.6 to 4.4 mg l⁻¹ with a mean of 3.5.

Bicarbonate: The bicarbonate content of runoff waters ranged from 10.5 to 18.2 mg l⁻¹ with a mean of 13.2.

NO₃-Nitrogen: The NO₃-nitrogen content of runoff waters ranged from 0.8 to 1.5 mg l⁻¹ with a mean of 1.13.

NH₄-Nitrogen: The NH₄-nitrogen content of runoff waters was found to be nil.

Table 45: Chemical characteristics and bacteriological quality of runoff water collected from Amberpet landfill site, Hyderabad dity

Sample Distance													
No.	from land fill site (m)	B.O.D	C.O.D.	Potas- sium	Sodium	Chlo- ride	Sul- phate	Phos- phate	Boron	CO ₃	HCO ₃	NO ₃ -N	NH ₄ -N
----- (mg l ⁻¹) -----													
1.	10	1.60	2.30	1.20	16.50	11.40	2.50	0.23	0.21	4.2	18.2	1.50	N11
2.	15	1.30	2.00	1.00	12.30	9.60	1.90	0.19	0.17	3.6	11.7	0.90	N11
3.	20	1.40	2.10	0.92	10.60	8.40	0.86	0.16	0.14	4.4	16.2	1.00	N11
4.	25	1.30	2.00	0.85	9.80	7.80	0.91	0.17	0.18	3.2	10.8	0.80	N11
5.	30	1.20	2.10	0.91	10.40	8.80	0.93	0.18	0.16	2.6	10.5	1.20	N11
6.	35	1.30	2.00	0.96	10.70	9.00	1.20	0.20	0.19	3.0	11.8	1.40	N11
Mean	--	1.35	2.08	0.97	11.71	9.16	1.38	0.18	0.17	3.5	13.2	1.13	-
Range	--	1.20	2.00	0.85	9.80	7.80	0.86	0.16	0.14	2.6	10.5	0.80	-
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Fluoride: The Fluoride content of runoff waters ranged from 0.10 to 0.15 mg l⁻¹ with a mean of 0.12.

4.5.1.3 Bacteriological quality

Coliform bacteria: The coliform bacteria were not detected in the runoff waters.

4.5.1.4 Micronutrient contents: The micronutrient contents of runoff waters ranged as follows:

Zinc ranged from 22 to 35 ug l⁻¹ with a mean of 28.5. Copper could not be detected in any one of the water samples. The iron content ranged from 105 to 184 ug l⁻¹ with a mean of 132.33. Whereas manganese content ranged from 44 to 76 ug l⁻¹ with a mean of 60.33.

4.5.1.5 Heavy metal contents: The heavy metal concentration of runoff waters ranged as follows:

The lead ranged from 20 to 32 ug l⁻¹ with a mean of 25.33. The nickel ranged from 9 to 13 ug l⁻¹ with a mean of 10.66. The chromium content ranged from 1.0 to 1.5 ug l⁻¹ with a mean of 1.26 whereas cadmium could not be detected. The cobalt ranged from 3.8 to 5.1 ug l⁻¹ with a mean of 4.41.

4.5.2 Characteristics of well waters located away from landfill sites

4.5.2.1 Physico-chemical Characteristics: The data pertaining to characteristics of well waters located away from landfill sites at Golkonda and Amberpet are presented in Tables 46 and 47, respectively.

pH: The pH of Golkonda well waters ranged from 7.1 to 8.1 with a mean of 7.63. In Amberpet well waters it ranged from 8.46 to 8.64 with a mean of 8.55 and 7.0 to 7.4 with a mean of 7.16 during monsoon and summer seasons, respectively.

Temperature: The temperature of well waters from Golkonda site ranged from 23 to 28°C with a mean of 25.16 whereas in well waters at Amberpet landfill site, they ranged from 26 to 29°C with a mean of 27.33 and from 24 to 28°C with a mean of 25.66 during monsoon and summer, respectively.

Electrical conductivity: The electrical conductivity of well waters at Golkonda landfill site ranged from 0.9 to 2.2 d S m⁻¹ with a mean of 1.48. In Amberpet, the E.C. of well waters ranged from 1.12 to 1.81 d S m⁻¹ with a mean of 1.4 during monsoon season and during summer season it ranged from 2.5 to 3.8 d S m⁻¹ with a mean of 2.88. Electrical conductivity increased during summer season when compared to monsoon season. In both the dumping sites the E.C. of well waters decreased with an increase in the distance from the landfill site.

Turbidity: The turbidity of water at Golkonda landfill site ranged from 1.0 to 3.0 NTU with a mean of 1.78 and in Amberpet it ranged from 1.1 to 2.05 NTU with a mean of 1.5 during monsoon season. In summer season it ranged from 0.5 to 3.2 NTU with a mean of 2.3. In general, the turbidity increased in summer when compared to monsoon season. In both the landfill sites, the turbidity of well waters decreased with increase in distance of wells from the fringe of the landfill sites.

Dissolved CO₂: The dissolved CO₂ of well waters of Golkonda site ranged from 1.4 to 10.0 mg l⁻¹ with a mean of 7.86. In Amberpet land fill site it ranged from 1.99 to 17.97 mg l⁻¹ with a mean of 13.97 in monsoon and from 3.2 to 18.5 mg l⁻¹ with a mean of 13.05 in summer. In general, the dissolved carbondioxide concentration decreased with increase in distance of wells at both the landfill sites.

Total Solids: The total solids content of well waters at Golkonda landfill site ranged from 800.0 to 2400.0 mg l⁻¹ with a mean of 1600.0, whereas in Amberpet landfill site, it ranged from 1000.0 to 1780.0 mg l⁻¹ with a mean of 1373.33 in monsoon and from 2000.0 to 3500.0 mg l⁻¹ with a mean of 2713.33 during summer seasons. The total solids concentration increased in summer as compared to monsoon. In both the landfill

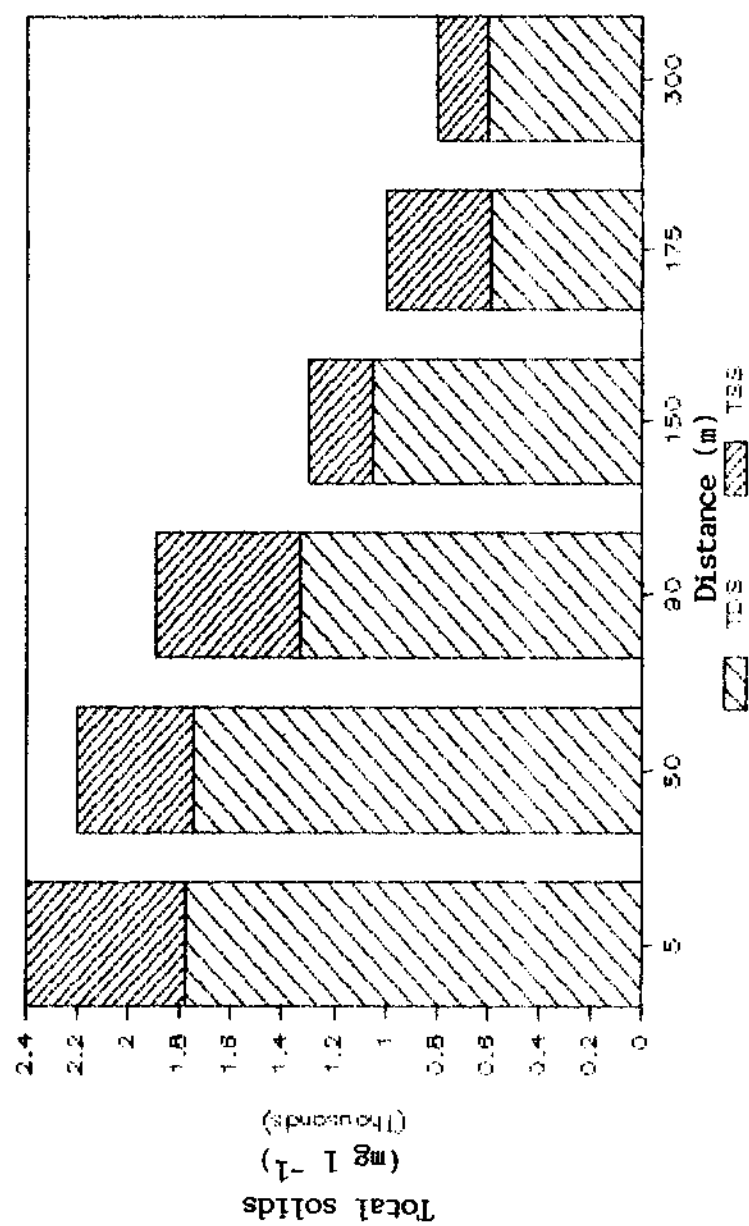


Fig. 7 Total solids concentration of water of wells located at Golkonda landfill site

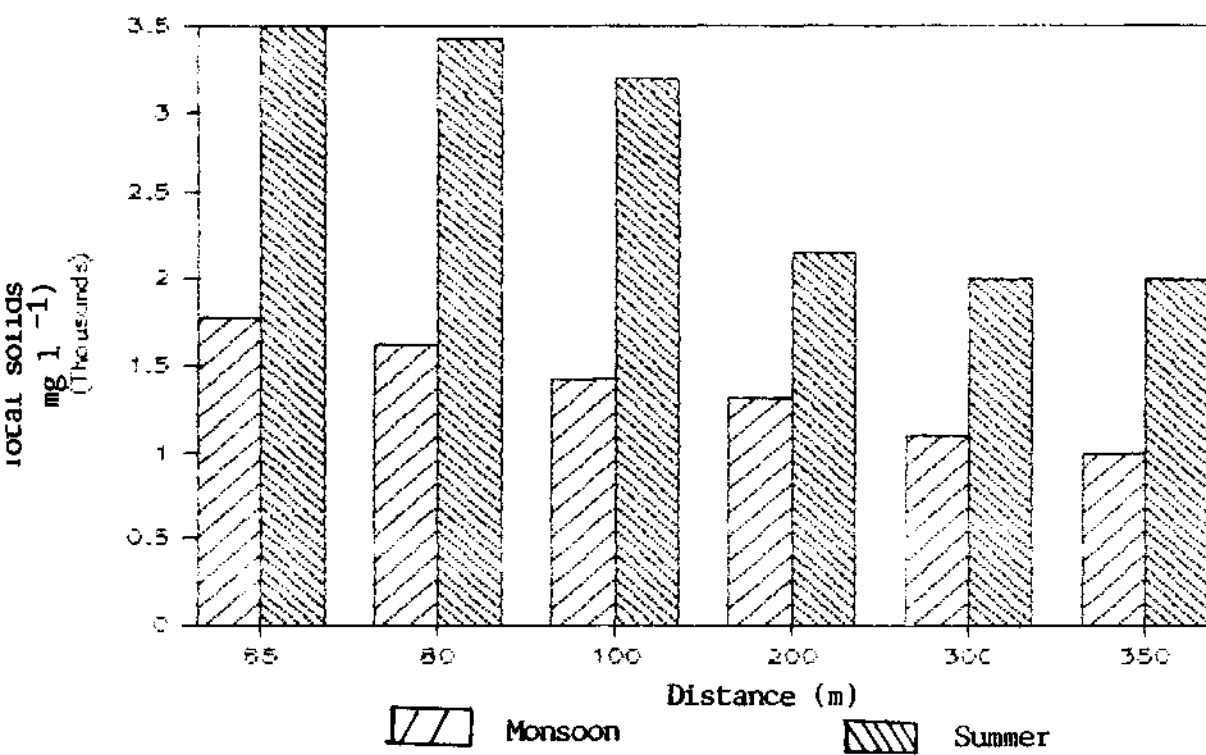


Fig. 8 Total solids concentration of water of wells located at Amberpet landfill site

sites, the total solids decreased as the distance of wells from the landfill sites increased (Fig. 7 and 8).

Total dissolved solids: The total dissolved solids of well waters from Golkonda site ranged from 588.0 to 1779.0 mg l^{-1} with a mean of 1182.6. In Amberpet site, it ranged from 826.0 to 1366.0 mg l^{-1} with a mean of 1093.0 during monsoon and from 1590.0 to 2800.0 mg l^{-1} with a mean of 2236.66 during summer season. In general, during summer season the TDS concentration tended to increase when compared with monsoon in Amberpet well waters. At both the sites, the total dissolved solids decreased as the distance of the wells from the landfill site increased.

Total suspended solids: The total suspended solids ranged from 206.0 to 621.0 mg l^{-1} with a mean of 417.3 in Golkonda water samples. In Amberpet water samples, it ranged from 174.0 to 414.0 mg l^{-1} with a mean of 280.33 in monsoon and from 340.0 to 700.0 mg l^{-1} with a mean of 476.66 in summer seasons. The TSS concentrations was more in summer than in monsoon. At both the sites, the TSS were low in wells situated at a distance from the landfill sites as compared to wells nearby.

Total Hardness (as CaCO_3): The total hardness of Golkonda well waters ranged from 200.0 to 874.0 mg l^{-1} with a mean of 476.0. In Amberpet well waters it

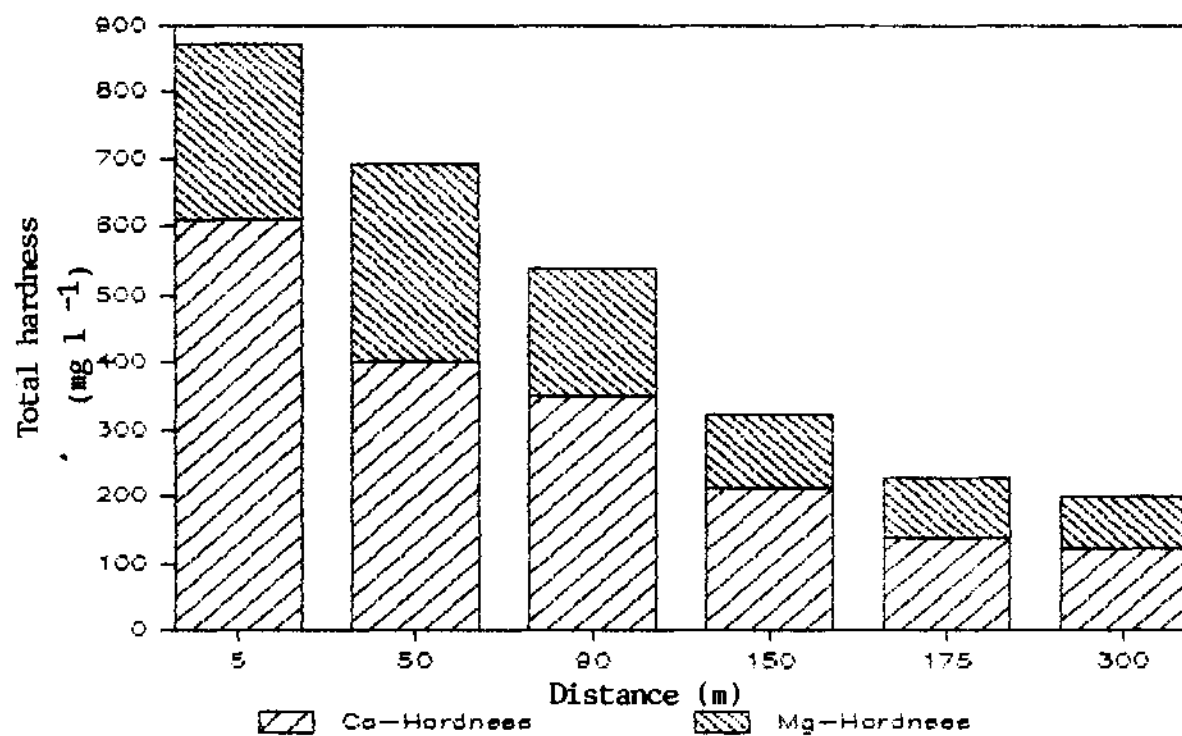


Fig. 9 Total hardness concentration of water of wells located at Golkonda landfill site

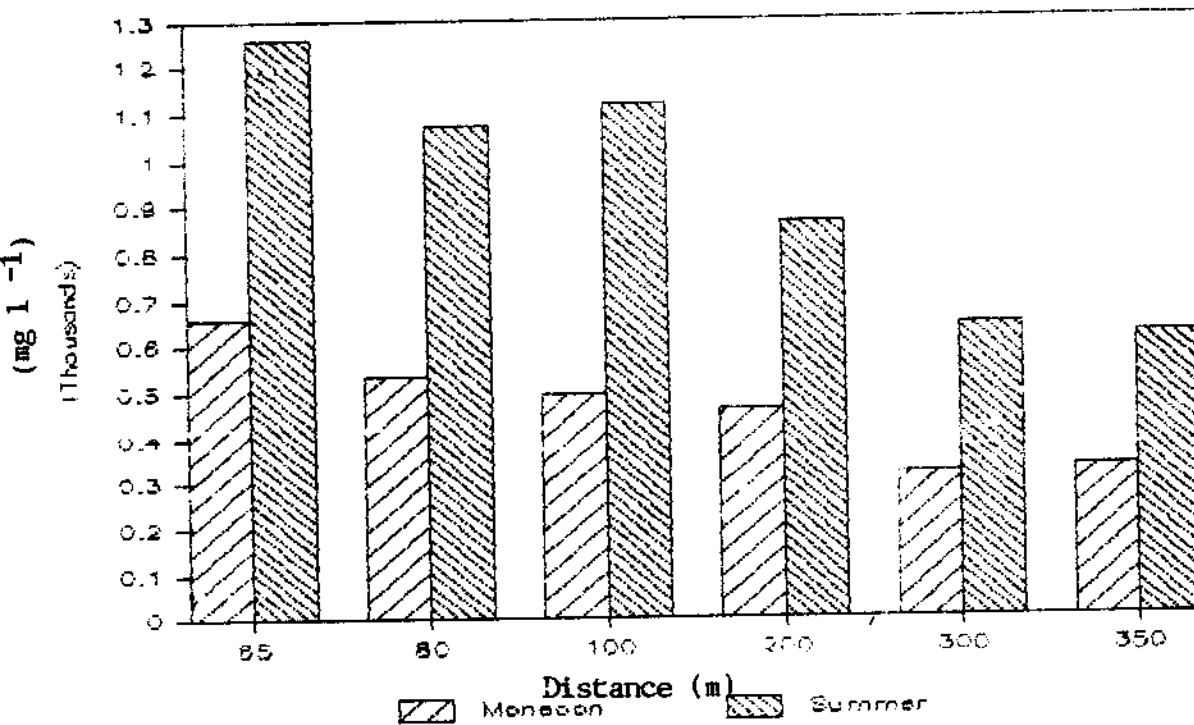


Fig. 10 Total hardness concentration of water of wells located at Amberpet landfill site

ranged from 317.0 to 660.0 mg l^{-1} with a mean of 465.6 in monsoon and from 620.0 to 1260.0 mg l^{-1} with a mean of 927.5 in summer season. It increased in summer season when compared to monsoon season. At both the sites, it decreased with increase in distance of wells from landfill sites (fig. 9 and 10).

Ca-Hardness (as CaCO_3): The Ca-hardness of Golkonda well waters ranged from 124.0 to 608.0 mg l^{-1} with a mean of 305.8. In Amberpet, it ranged from 215.0 to 480.0 mg l^{-1} with a mean of 333.3 during monsoon and from 480.0 to 860.0 mg l^{-1} with a mean of 620.83 in summer season. In general, it increased in summer when compared with monsoon season. At both the landfill sites, it decreased with increase in distance of wells from landfill sites.

Mg-Hardness (as CaCO_3): The Mg-hardness in Golkonda water samples ranged from 76.0 to 290.0 mg l^{-1} with a mean of 170.1. In Amberpet, it ranged from 67.0 to 180.0 mg l^{-1} with a mean of 132.3 in monsoon and from 110 to 495 mg l^{-1} with a mean of 306.6 during summer. It increased in summer season when compared with monsoon. At both the sites, it decreased with increase in distance of wells from the landfill sites.

Dissolved oxygen: The dissolved oxygen content of Golkonda well waters ranged from 4.6 to 7.4 mg l^{-1}

with a mean of 6.2. In Amberpet it ranged from 4.6 to 7.5 mg l^{-1} with a mean of 6.70 in monsoon and from 3.7 to 7.4 mg l^{-1} with a mean of 6.1 in summer. The D.O. concentration was the lowest in the wells located nearer to the landfill site. No clear trend in concentration of D.O. with location in terms of distance from the landfill site was apparent.

Carbonate hardness: The carbonate hardness of well waters ranged from 200.0 to 874.0 mg l^{-1} with a mean of 476.0 at Golkonda landfill site. In Amberpet it ranged from 252.0 to 660.0 mg l^{-1} with a mean of 445.6 in monsoon and from 620.0 to 1260.0 mg l^{-1} with a mean of 927.5 in summer seasons. The carbonate hardness of water increased in summer season when compared with monsoon. In general the carbonate hardness of water decreased with increase in distance of wells from the landfill site, at both the locations.

Non-alkaline hardness: The non-alkaline hardness of water was not detected in Golkonda landfill site water samples but at Amberpet landfill site, the hardness was detected in well No. 3 (40 mg l^{-1}) and well No. 8 (80 mg l^{-1}) in monsoon. In summer, the hardness could not be detected. In general, the non-alkalinity hardness content of well waters was found to be minimum or non-existent at both the sites.

Total Alkalinity: The total alkalinity content of Golkonda water samples ranged from 156.0 to 630.0 mg l⁻¹ with a mean of 428.6. In Amberpet, it ranged from 194.0 to 496.0 mg l⁻¹ with a mean of 334.6 in monsoon and from 280.0 to 1115.0 mg l⁻¹ with a mean of 737.3 in summer. It was more in summer when compared with monsoon. In general, it decreased with increase in distance of wells from landfill sites at both the locations.

Phenolphthalein (P)-Alkalinity: The P-alkalinity content of Golkonda water samples ranged from 16.0 to 40.0 mg l⁻¹ with a mean of 30.3. At Amberpet it ranged from 36.0 to 56.0 mg l⁻¹ with a mean of 49.0 in monsoon and from 50.0 to 110.0 mg l⁻¹ with a mean of 77.1 in summer. It was more in summer season when compared with monsoon. In general it decreased with increase in distance of wells from landfill sites at both the locations.

Methyl orange (Mo)-Alkalinity: The Mo-alkalinity of Golkonda well waters ranged from 120.0 to 720.0 mg l⁻¹ with a mean of 398.3. At Amberpet it ranged from 150 to 460.0 mg l⁻¹ with a mean of 285.6 in monsoon and from 230.0 to 1005.0 mg l⁻¹ with a mean of 661.0 in summer season. It was more during summer when compared with monsoon. In general, it decreased with increase in distance of wells at both the landfill sites.

Table 46 : Physico-chemical characteristics of well waters collected from Golkonda landfill site, Hyderabad city

Well No.	Distance from landfill site (m)	pH	Temp. °C	E.C. d Sm ⁻¹	Turbidity (NTU)	Dissolved CO ₂	Total solids	Total dissolved solids	Total suspended solids
----- (mg l ⁻¹) -----									
1.	5	7.8	23.0	2.20	3.0	10.0	2400.0	1779.0	621.0
2.	50	8.1	25.0	1.95	2.2	8.5	2200.0	1750.0	450.0
3.	90	7.5	24.0	1.60	2.0	9.6	1900.0	1332.0	568.0
4.	150	7.1	26.0	1.24	1.5	1.4	1300.0	1053.0	247.0
5.	175	7.7	25.0	1.00	1.0	8.7	1000.0	588.0	412.0
6.	300	7.6	28.0	0.90	1.0	9.0	800.0	594.0	206.0
Mean	--	7.63	25.16	1.48	1.78	7.86	1600.0	1782.6	417.3
Range	--	7.1 to 8.1	23.0 to 28.0	0.90 to 2.20	1.0 to 3.0	1.4 to 10.0	800.0 to 2400.0	588.0 to 1779.0	206.0 to 621.0
=====									
Well No.	Distance from landfill site (m)	Total hardness as CaCO ₃	Ca-hardness as CaCO ₃	Mg-hardness as CaCO ₃	Dissolved oxygen	Carbonate hardness	Non-Alkali-nity	Total Alkali-nity	P-MO-Alkali-nity
----- (mg l ⁻¹) -----									
1.	5	874.0	608.0	266.0	4.6	874.0	Nil	756.0	36.0
2.	50	690.0	400.0	290.0	6.2	690.0	Nil	630.0	30.0
3.	90	540.0	350.0	190.0	6.5	540.0	Nil	504.0	24.0
4.	150	324.0	213.0	111.0	6.1	324.0	Nil	316.0	16.0
5.	175	228.0	140.0	88.0	6.4	228.0	Nil	210.0	40.0
6.	300	200.0	124.0	76.0	7.4	200.0	Nil	156.0	36.0
Mean	--	476.0	305.8	170.1	6.2	476.0	--	428.6	30.3
Range	--	200.0 to 874.0	124.0 to 608.0	76.0 to 290.0	4.6 to 7.4	200.0 to 874.0	--	156.0 to 630.0	16.0 to 40.0
=====									

Table 47 : Physico-chemical characteristics of well waters collected from Amberpet landfill site, Hyderabad city

Well No.	Distance from landfill site (m)	pH		Temp. °C		E.C., d Sm ⁻¹		Turbidity (NTU)		Dissolved CO ₂		Total solids		Total dissolved solids (mg l ⁻¹)		Total suspended solids		Total hardness as CaCO ₃	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1.	65	8.54	7.00	27.00	26.00	1.81	3.40	2.05	3.2	17.97	18.5	1780.00	3500.0	1366.0	2800.00	414.00	700.00	660.0	1260.0
2.	80	8.51	7.30	27.00	24.00	1.6	3.80	1.47	3.0	17.97	16.2	1620.00	3420.0	1226.0	2790.00	394.00	630.00	533.0	1070.0
3.	100	8.46	7.20	27.00	25.00	1.4	2.50	1.65	3.1	15.98	14.5	1420.00	3200.0	1186.0	2800.00	234.00	400.00	493.0	1115.0
4.	200	8.64	7.00	26.00	24.00	1.31	2.50	1.54	3.0	13.98	13.6	1320.00	2160.0	1060.0	1780.00	260.00	380.00	459.0	860.0
5.	300	8.63	7.40	28.00	27.00	1.21	2.60	1.25	1.0	15.94	12.3	1100.00	2000.0	894.0	1660.00	206.00	340.00	317.0	640.0
6.	350	8.57	7.10	29.00	28.00	1.12	2.50	1.10	0.5	1.99	3.2	1000.00	2000.0	826.0	1590.00	174.00	410.00	332.0	620.0
Mean	--	8.55	7.16	27.33	25.66	1.40	2.88	1.50	2.3	13.97	13.05	1373.33	2713.3	1093.0	2236.66	280.33	476.66	465.6	927.5
Range	--	8.46	7.00	26.00	24.00	1.12	2.50	1.10	0.5	1.99	3.2	1000.00	2000.0	826.0	1590.00	174.00	340.00	317.0	620.0
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to
		8.64	7.40	29.00	28.00	1.81	3.80	2.05	3.2	17.97	18.5	1780.00	3500.0	1366.0	2800.00	414.00	700.00	660.0	1260.0

Contd...

(Contd... Table 47)

Well No.	Distance from landfill site (m)	Ca-hardness as CaCO_3		Mg-hardness as CaCO_3		Dissolved Oxygen		Carbonate Hardness		Non-Alkaline hardness		Total Alkalinity		P-Alkalinity		MO-Alkalinity	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1.	65	480.0	860.00	180.0	400.0	4.6	3.7	660.0	1260.0	N11	N11	496.0	1115.0	36.0	110.0	460.0	1005.0
2.	80	375.0	640.00	158.0	430.0	6.3	6.0	533.0	1070.0	N11	N11	474.0	912.0	54.0	98.0	420.0	814.0
3.	100	350.0	620.00	143.0	495.0	6.9	6.1	453.0	1115.0	40.0	N11	306.0	843.0	56.0	79.0	250.0	764.0
4.	200	315.0	595.00	144.0	265.0	7.4	6.2	459.0	860.0	N11	N11	274.0	740.0	54.0	67.0	220.0	673.0
5.	300	215.0	530.00	102.0	110.0	7.4	7.2	317.0	640.0	N11	N11	264.0	534.0	50.0	59.0	214.0	480.0
6.	350	265.0	480.00	67.0	140.0	7.5	7.4	252.0	620.0	80.0	N11	194.0	280.0	44.0	50.0	150.0	230.0
Mean	--	333.3	620.83	132.3	306.6	6.7	6.1	445.6	927.5	20.0	N11	334.6	737.3	49.0	77.1	285.6	661.0
Range	--	215.0	480.00	67.0	110.0	4.6	3.7	252.0	620.0	0.0	N11	194.0	280.0	36.0	50.0	150.0	230.0
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to
		480.0	860.00	180.0	495.0	7.5	7.4	660.0	1260.0	80.0		496.0	1115.0	56.0	110.0	460.0	1005.0

A = Monsoon B = Summer

4.5.2.2 Chemical characteristics of well waters

The data are presented in Table 48 and 49.

Biochemical oxygen demand (B.O.D.): The B.O.D. of Golkonda water samples ranged from 0.6 to 13.0 mg l⁻¹ with a mean of 4.18. The highest B.O.D. of 13.0 mg l⁻¹ was recorded in the waters of the well located nearest to the landfill site (Fig. 11). Whereas in Amberpet it ranged from 0.5 to 15.5 mg l⁻¹ with a mean of 5.53 in monsoon and from 0.4 to 17.0 mg l⁻¹ with a mean of 5.6 in summer. The highest B.O.D. was observed in well nearer to the landfill site where it was found to be 15.5 and 17.0 mg l⁻¹ in monsoon and summer seasons, respectively. In general, the B.O.D. of well waters decreased with increase in distance of wells from the landfill sites.

Chemical oxygen demand (C.O.D.): The C.O.D. of well waters ranged from 1.4 to 24.0 mg l⁻¹ with a mean of 11.8 at Golkonda landfill site (Fig. 11). It ranged from 1.2 to 21.0 mg l⁻¹ with a mean of 9.05 in monsoon and from 1.1 to 24.0 mg l⁻¹ with a mean of 10.3 in summer season at Amberpet landfill site. In general it decreased with increase in distance of wells from landfill sites.

Potassium: The potassium content of well waters ranged from 8.0 to 26.0 mg l⁻¹ with a mean of 18.0 at

Golkonda landfill site. It ranged from 4.7 to 23.3 mg l⁻¹ with a mean of 10.38 in monsoon and from 4.8 to 57.6 mg l⁻¹ with a mean of 19.86 in summer at Amberpet landfill site. In general, it decreased with increase in distance of wells from landfill sites and appear to follow the same trend as that recorded with total dissolved solids.

Sodium: The sodium content in well waters obtained from the landfill site at Golkonda ranged from 100.0 to 450.0 mg l⁻¹ with a mean of 249.3 (Fig. 11). It ranged from 200.0 to 342.0 mg l⁻¹ with a mean of 281.16 in monsoon and from 1160.0 to 1560.0 mg l⁻¹ with a mean of 1373.3 in summer season at Amberpet landfill site. It was more in summer when compared with monsoon. In general the sodium content decreased with increase in distance of wells from landfill sites.

Chloride: The chloride content of well waters ranged from 74.0 to 269.0 mg l⁻¹ with a mean of 173.6 at Golkonda site (Fig. 11). At Amberpet landfill site it ranged from 167.0 to 245.0 mg l⁻¹ with a mean of 203.8 in monsoon and from 480.0 to 935.0 mg l⁻¹ with a mean of 685.0 in summer. It was more in summer season when compared with monsoon. In general, it decreased with increase in distance of wells from landfill sites at both the locations.

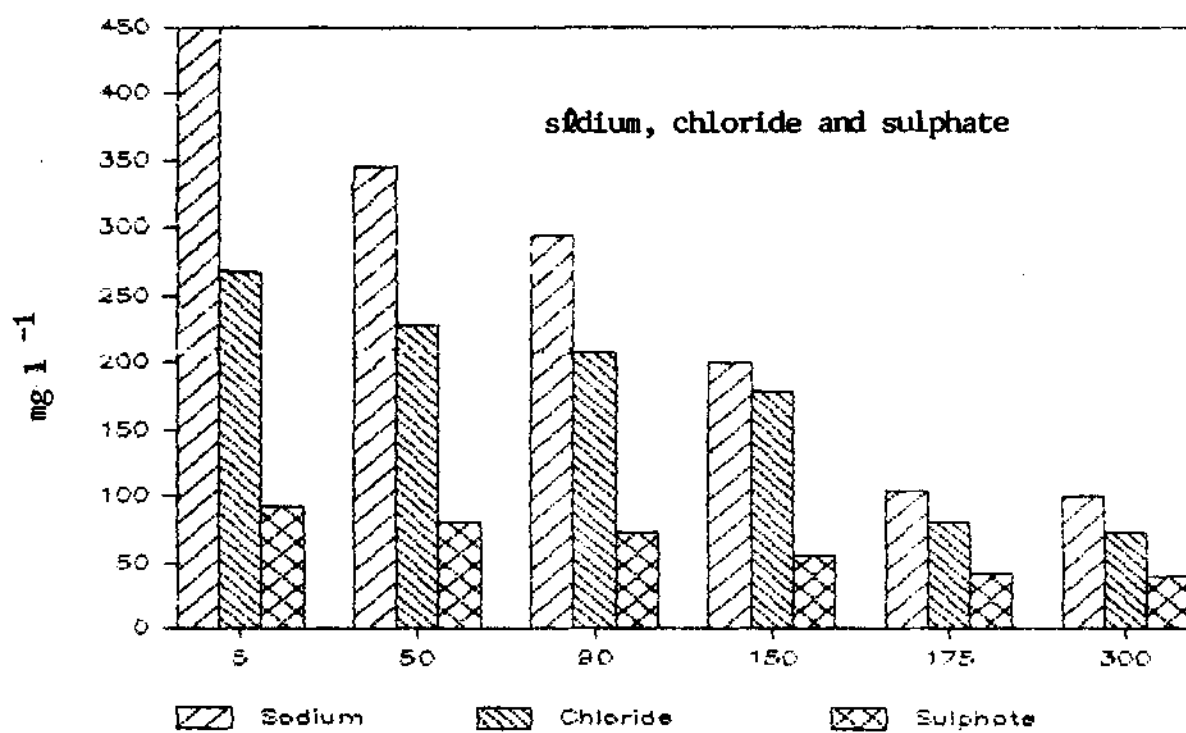
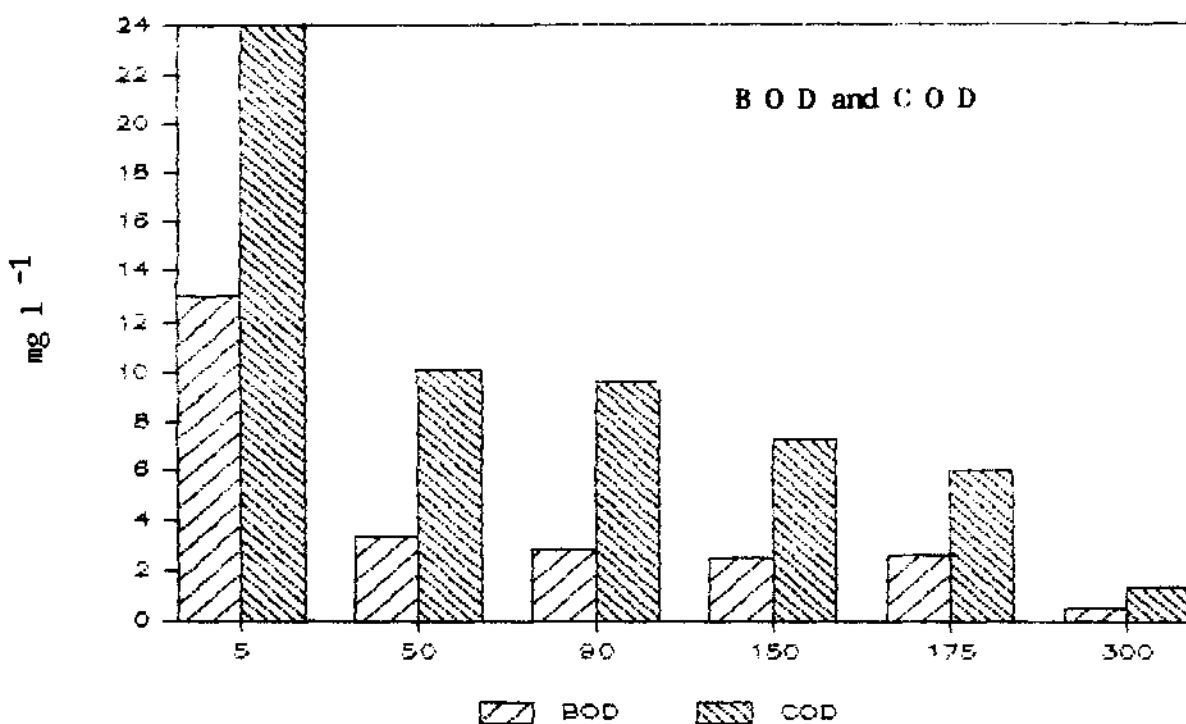


Fig. 11 Chemical characteristics of well waters at Golkonda landfill site

Sulphate: The sulphate content of water samples from Golkonda landfill site ranged from 39.0 to 92.0 mg l⁻¹ with a mean of 64.1 (Fig. 11). Whereas at Amberpet it ranged from 48.0 to 71.0 mg l⁻¹ with a mean of 59.6 in monsoon and from 105.0 to 240.0 mg l⁻¹ with a mean of 167.16. It was more in summer as compared to monsoon. In general, the sulphate concentration decreased in the water samples with increase in distance of wells from landfill site.

Phosphate: The phosphate content of well waters ranged from 0.4 to 2.8 mg l⁻¹ with a mean of 1.56 at Golkonda landfill site. It ranged from 0.72 to 2.0 mg l⁻¹ with a mean of 1.3 in monsoon and from 1.0 to 3.0 mg l⁻¹ with a mean of 1.8 in summer at Amberpet. In general, it was more in summer as compared to monsoon. It decreased with increase in distance of wells from sites at both the locations.

Boron: The boron content of well waters as Golkonda ranged from 0.3 to 1.9 mg l⁻¹ with a mean of 1.1. At Amberpet landfill site, the boron content of well water ranged from 0.4 to 1.4 mg l⁻¹ with a mean of 0.76 in monsoon and from 0.5 to 2.2 mg l⁻¹ with a mean of 1.4 in summer. It was more in summer season when compared with monsoon. In general, it decreased with increase in distance of wells from landfill sites at both the locations.

Carbonates: The carbonate content of well waters ranged from 32 to 80 mg l^{-1} with a mean of 60.6 at Golkonda landfill site whereas it ranged from 72 to 112 mg l^{-1} with a mean of 98.0 in monsoon and from 100 to 220 mg l^{-1} with a mean of 154.3 in summer season at Amberpet dumping ground.

Bi-carbonates: The bi-carbonate content of Golkonda well waters ranged from 84 to 684 mg l^{-1} with a mean of 371.0 whereas in Amberpet well waters it ranged from 106 to 424 mg l^{-1} with a mean of 236.6 in monsoon and from 180 to 895 mg l^{-1} with a mean of 583.0. In summer the concentration of bi-carbonates content in well waters was more than in monsoon. It decreased with increase in distance of wells from landfill sites.

NO_3 -Nitrogen: The NO_3 -nitrogen content of Golkonda well waters ranged from 1.5 to 10.0 mg l^{-1} with a mean of 5.9 and in Amberpet landfill site it ranged from 2.0 to 8.0 mg l^{-1} with a mean of 4.6 in monsoon and from 2.8 to 13.5 mg l^{-1} with a mean of 7.3 in summer at Amberpet dumping site. It was more in summer when compared with monsoon. In general it decreased with increase in distance of well from landfill sites.

NH_4 -nitrogen: The NH_4 -nitrogen content of Golkonda water samples ranged from nil to 0.3 mg l^{-1} with a mean of 0.14. In well numbers 5 and 6 NH_4 -N could not be detected whereas in Amberpet it ranged from

Table 48 : Chemical characteristics and bacteriological quality of well waters collected from Golkonda landfill site, Hyderabad city

Well No.	Distance from landfill site (m)	B.O.D	C.O.D.	Potas- sium	Sodium	Chlo- ride	Sul- phate	Phos- phate as PO ₄	Boron	CO ₃	HCO ₃	NO ₃ -N	NH ₄ -N
1.	5	13.00	24.0	26.0	450.0	269.0	92.0	2.80	1.90	72.0	684.0	10.0	0.30
2.	50	3.40	10.1	22.0	346.0	229.0	82.0	2.10	1.80	60.0	570.0	9.0	0.25
3.	90	2.90	9.6	21.0	294.0	209.0	74.0	1.80	1.60	48.0	454.0	8.0	0.20
4.	150	2.50	7.2	19.0	201.0	179.0	56.0	1.40	0.70	32.0	304.0	4.5	0.12
5.	175	2.70	6.0	12.0	105.0	82.0	42.0	0.90	0.35	80.0	130.0	2.5	N11
6.	300	0.60	1.4	8.0	100.0	74.0	39.0	0.40	0.30	72.0	84.0	1.5	N17
Mean	--	4.18	11.8	18.0	249.3	173.6	64.1	1.56	1.10	60.6	371.0	5.9	0.14
Range	--	0.60 to 13.00	1.4 to 24.0	8.0 to 26.0	100.0 to 450.0	74.0 to 269.0	39.0 to 92.0	0.40 to 2.80	0.30 to 1.90	32.0 to 80.0	84.0 to 684.0	1.5 to 10.0	N11 to 0.30

Contd...

(Contd...Table 48)

Well No.	Distance from land fill site (m)	Fluoride (mg l ⁻¹)	Micronutrients (ug l ⁻¹)				Heavy metals (ug l ⁻¹)				Coliform bacteria (MPN)	
			Zn	Cu	Fe	Mn	Pb	Ni	Cr	Co		Cd
1.	5	0.23	60.00	ND	100.0	400.0	38.00	9.00	9.00	8.00	ND	ND
2.	50	0.20	20.00	ND	600.0	100.0	9.00	4.00	3.70	7.00	ND	ND
3.	90	0.21	30.00	ND	1300.0	200.0	11.00	5.00	1.50	8.00	ND	ND
4.	150	0.15	300.00	ND	1300.0	500.0	6.00	8.00	4.50	10.00	ND	ND
5.	175	0.18	100.00	ND	700.0	800.0	33.00	4.00	6.00	9.00	ND	ND
6.	300	0.15	27.00	ND	800.0	800.0	8.80	4.00	5.40	5.00	ND	ND
Mean	--	0.18	91.16	--	800.0	466.6	17.63	5.66	5.01	7.83	--	--
Range	--	0.15 to 0.23	20.00 to 300.00	--	100.0 to 1300.0	100.0 to 800.0	6.00 to 38.00	4.00 to 9.00	1.50 to 5.00	5.00 to 10.00	--	--

ND : Not detected.

Table 49 : Chemical characteristics and bacteriological quality of well waters collected from Amberpet landfill site, Hyderabad city

Well No.	Distance from landfill site (m)	B.O.D		C.O.D		Potas- sium		Sodium		Chlo- ride		Sul- phate		Phos- phate as PO_4	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B
1.	65	15.50	17.0	21.00	24.0	23.30	57.60	342.00	1560.0	245.0	935.0	71.0	240.00	2.00	3.0
2.	80	3.50	5.4	8.40	12.3	13.30	22.40	326.00	1500.0	221.0	860.0	66.0	195.00	1.54	2.6
3.	100	4.50	4.6	6.40	10.1	5.00	15.20	315.00	1360.0	201.0	635.0	61.0	162.00	1.17	2.2
4.	200	5.10	3.8	9.20	8.2	4.70	12.80	300.00	1340.0	200.0	610.0	58.0	155.00	1.32	1.8
5.	300	4.10	2.4	8.10	6.1	9.70	4.80	204.00	1320.0	189.0	590.0	54.0	122.00	1.25	1.6
6.	350	0.50	0.4	1.20	1.1	6.30	6.40	200.00	1160.0	167.0	480.0	48.0	105.00	0.72	1.0
Mean	--	5.53	5.6	9.05	10.3	10.38	19.86	281.16	1373.3	203.8	685.0	59.6	163.16	1.30	1.8
Range	--	0.50 to 15.50	0.4 to 17.0	1.20 to 21.00	1.1 to 24.0	4.70 to 23.30	4.80 to 57.60	200.00 to 342.00	1167.0 to 1560.0	160.0 to 245.0	480.0 to 935.0	48.0 to 71.0	105.00 to 240.00	0.72 to 2.00	1.0 to 3.0

Contd ...

(Contd....Table 49)

Well No.	Distance from land-fill site (m)	Boron		CO ₃		HCO ₃		NO ₃ -N		NH ₄ -N		Fluoride		Coliform bacteria (MPN)	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B
1.	65	1.40	2.2	72.0	220.0	424.0	895.0	8.0	13.5	0.20	0.40	0.40	0.22	ND	ND
2.	80	0.90	1.8	108.0	196.0	366.0	716.0	6.0	10.5	0.20	0.20	0.30	0.18	ND	ND
3.	100	0.80	1.6	112.0	158.0	194.0	685.0	5.0	8.2	0.20	0.10	0.20	0.12	ND	ND
4.	200	0.60	1.3	108.0	134.0	166.0	606.0	4.0	5.6	0.10	0.10	0.20	0.16	ND	ND
5.	300	0.50	1.0	100.0	118.0	164.0	416.0	3.0	3.2	0.10	0.10	0.25	0.15	ND	ND
6.	350	0.40	0.5	88.0	100.0	106.0	180.0	2.0	2.8	ND	ND	0.15	0.13	ND	ND
Mean	--	0.76	1.4	98.0	154.3	236.6	583.0	4.6	7.3	0.13	0.15	0.25	0.16	--	--
Range	--	0.40 to 1.40	0.5 to 2.2	72.0 to 112.0	100.0 to 220.0	106.0 to 424.0	180.0 to 895.0	2.0 to 8.0	2.8 to 13.5	ND to 0.20	ND to 0.40	0.15 to 0.40	0.12 to 0.22	--	--

A : Monsoon B : Summer ND : Not detected

nil to 0.2 mg l^{-1} with a mean of 0.13 in monsoon and from nil to 0.4 mg l^{-1} with a mean of 0.15 in summer. In well number 6 at Amberpet landfill site, $\text{NH}_4\text{-N}$ could not be detected. In general, it decreased with increase in distance of wells from land fill sites at both the locations.

Fluoride: The fluoride content of well waters ranged from 0.15 to 0.23 mg l^{-1} with a mean of 0.18 at Golkonda landfill site. At Amberpet it ranged from 0.15 to 0.4 mg l^{-1} with a mean of 0.25 in monsoon and from 0.12 to 0.22 mg l^{-1} with a mean of 0.16 in summer season. In general, it decreased with increase in distance of wells from landfill sites at both the locations.

4.5.2.3 Bacteriological quality

Coliforms: The coliform bacteria were not detected in the well water samples collected from Amberpet and Golkonda landfill sites.

4.5.2.4 Micronutrients and heavy metals in well waters

The data are presented in Tables 48 and 50.

Zinc: The zinc content of Golkonda water samples ranged from 20.0 to 300.0 ug l^{-1} with a mean of 91.16. In Amberpet it ranged from 150.0 to 450.0 ug l^{-1} with a mean of 345.0 in monsoon and from 280.0 to 580.0 ug l^{-1} with a mean of 390.0 in summer season.

Copper: Copper was not detected in all the well waters samples at the Golkonda landfill site. At the Amberpet landfill sites the water samples contained copper ranging from 2.0 to 4.0 $\mu\text{g l}^{-1}$ with a mean of 3.0 in monsoon and from 2.0 to 5.0 $\mu\text{g l}^{-1}$ with a mean of 3.8 in summer season.

Iron: The iron content of Golkonda water samples ranged from 100.0 to 1300.0 $\mu\text{g l}^{-1}$ with a mean of 800.0 whereas at Amberpet landfill site, the water samples contained iron and it ranged from 700.0 to 1500.0 $\mu\text{g l}^{-1}$ in monsoon and 840.0 to 1400.0 $\mu\text{g l}^{-1}$ with a mean of 1066.6 in summer season.

Manganese: The manganese content of water samples from Golkonda landfill site ranged from 100.0 to 800.0 $\mu\text{g l}^{-1}$ with a mean of 466.6. While in the water samples obtained from Amberpet landfill site the manganese contents ranged from 200.0 to 809.0 $\mu\text{g l}^{-1}$ with a mean of 506.6 in monsoon and from 375 to 930 $\mu\text{g l}^{-1}$ with a mean of 781.6 in summer season.

Lead: The lead content in well waters of Golkonda landfill site ranged from 6.0 to 38.0 $\mu\text{g l}^{-1}$ with a mean of 17.63 whereas in Amberpet, it ranged from 8.9 to 31.5 $\mu\text{g l}^{-1}$ with a mean of 17.35 in monsoon and from 9.0 to 34.5 $\mu\text{g l}^{-1}$ with a mean of 20.06 in summer season.

Table 50 : Micronutrient and heavy metal content of well waters collected from Amberpet landfill site, Hyderabad city

Well No.	Distance from the landfill site (m)	Zinc		Copper		Iron		Manganese		Lead ($\mu\text{g l}^{-1}$)		Nickle		Chromium		Cobalt		Cadmium	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	65	360.0	580.0	3.0	5.0	894.0	1400.0	744.0	910.0	31.5	34.50	7.10	8.50	5.00	7.00	6.10	6.5	ND	ND
2	80	150.0	430.0	3.0	4.0	700.0	1200.0	200.0	815.0	8.9	16.40	6.00	7.45	6.00	7.00	8.40	9.4	ND	ND
3	100	380.0	380.0	4.0	3.0	1200.0	980.0	572.0	930.0	21.3	23.00	6.40	7.30	8.70	10.00	9.60	9.8	ND	ND
4	200	320.0	360.0	4.0	5.0	640.0	840.0	285.0	375.0	12.0	18.00	5.10	6.40	7.80	9.00	9.10	9.5	ND	ND
5	300	410.0	280.0	2.0	4.0	874.0	970.0	430.0	745.0	21.0	19.50	7.50	7.80	7.00	9.00	7.50	8.1	ND	ND
6	350	450.0	310.0	2.0	2.0	1500.0	1010.0	809.0	915.0	9.4	9.00	4.30	5.10	4.01	5.50	3.60	4.1	ND	ND
Mean		345.0	390.0	3.0	3.8	968.0	1066.6	506.6	781.6	17.3	20.06	6.06	7.09	6.40	7.91	7.38	7.9	--	--
Range		150.0	280.0	2.0	2.0	700.0	840.0	200.0	375.0	8.9	9.0	4.30	5.10	4.00	5.50	3.60	4.1	--	--
		to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to
		450.0	580.0	4.0	4.0	1500.0	1400.0	809.0	930.0	31.5	34.5	7.50	8.50	8.70	10.00	9.60	9.8		

A = Monsoon

B = Summer

ND = Not Detected

Nickel: The nickel content of water samples obtained from Golkonda landfill site ranged from 4.0 to 9.0 $\mu\text{g l}^{-1}$ with a mean of 5.66 whereas in Amberpet, it ranged from 4.3 to 7.5 $\mu\text{g l}^{-1}$ with a mean of 6.06 in monsoon and from 5.1 to 8.5 $\mu\text{g l}^{-1}$ with a mean of 7.09 in summer season.

Chromium: The chromium content of well waters collected from Golkonda landfill site ranged from 1.5 to 9.0 $\mu\text{g l}^{-1}$ with a mean of 5.01 whereas in Amberpet, it ranged from 4.0 to 8.7 $\mu\text{g l}^{-1}$ with a mean of 6.41 in monsoon season and from 5.5 to 10.0 $\mu\text{g l}^{-1}$ with a mean of 7.91 in summer season.

Cobalt: The cobalt content of well waters of Golkonda ranged from 5.0 to 10.0 $\mu\text{g l}^{-1}$ with a mean of 7.83 whereas in Amberpet, it ranged from 3.6 to 9.6 $\mu\text{g l}^{-1}$ with a mean of 7.38 in monsoon and from 4.1 to 9.8 $\mu\text{g l}^{-1}$ with a mean of 7.9 in summer season.

Cadmium: Cadmium content could not be detected in well water samples from Amberpet and Golkonda landfill sites.

4.6 RESPONSE OF MAIZE TO WASTE APPLICATION AND UPTAKE OF MICRONUTRIENTS AND HEAVY METALS

Urban solid wastes are a rich source of decomposable organic matter and, hence, can be used as a

manure or alternatively briquetted and, burnt as a fuel. It is, however not very suitable for energy recycling though production of biogas as the decomposable organic matter is less in wastes generated in many Indian cities. To ascertain the impact of the urban solid wastes generated in Hyderabad City on the accumulation of micronutrients and heavy metal toxicants in soil and plant, a potculture experiment was conducted with different levels of application of USW and FYM with a control. The test crop employed was maize. The yield and uptake of micronutrients by maize and the hazard of increased uptake of heavy metals, if any, by maize was also investigated. The stabilized wastes from Amberpet and Golkonda and fresh wastes from Golkonda only were used in the study.

4.6.1 Effect of application of wastes on maize dry matter yield

The data are depicted in Fig. 12. The application of urban solid wastes whether stabilized or fresh increased the dry matter yield of maize over control except with Amberpet stabilized waste (ASW) applied at 11.0 t ha^{-1} . The dry matter yield differences observed in the different treatments were, however, not significant. On the other hand, application of FYM at doses in excess of 22 t ha^{-1} increased the dry matter yield of maize significantly.

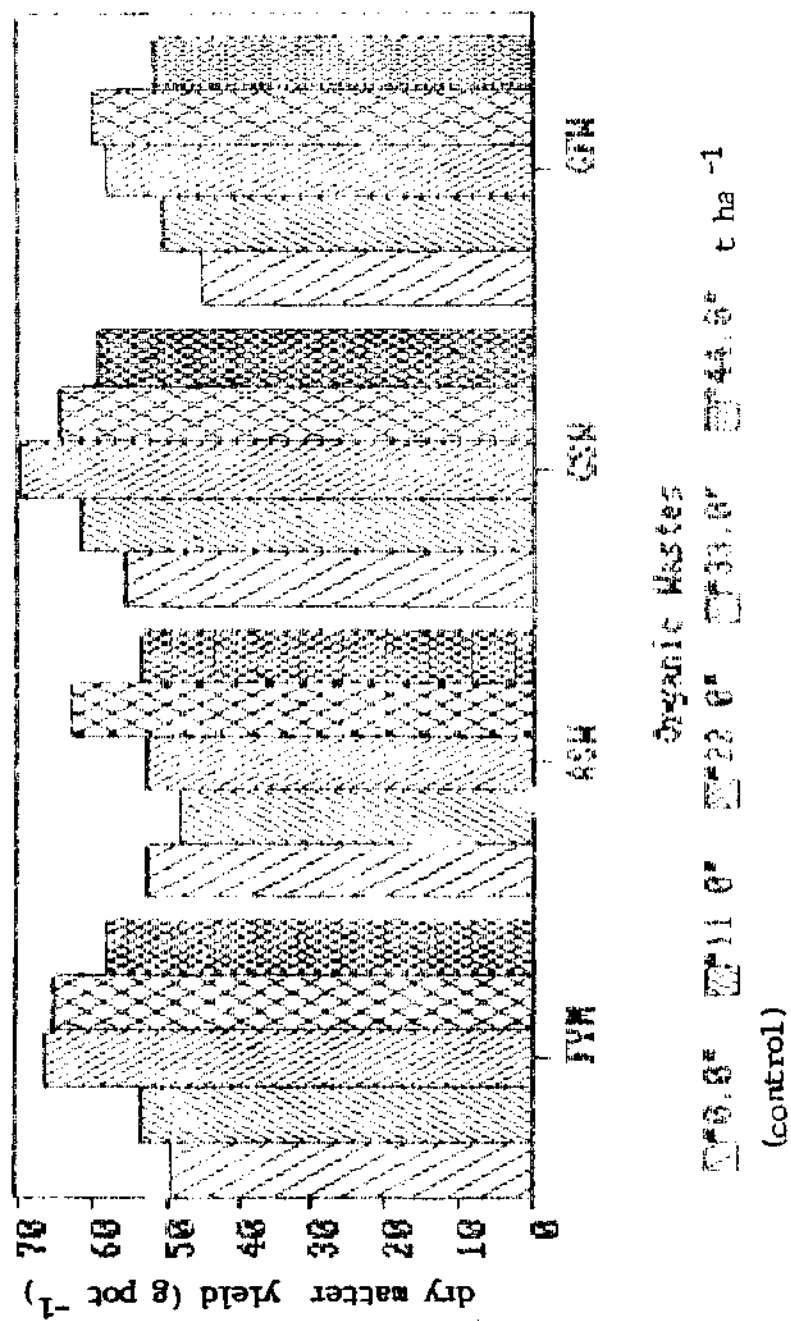


Fig. 12 Dry matter yield of maize as affected by application of USW and FYM

4.6.2 Effect of organic wastes on uptake of micronutrients and heavy metals by maize crop

The total uptake of micronutrients and heavy metals in the shoot (stem + leaf) portion was computed from the dry matter accumulation (stem + leaf) and micronutrient and heavy metal contents.

4.6.2.1 Micronutrient uptake: The data pertaining to uptake of micronutrients are presented in Table 51 which reveals that application of FYM and organic wastes decreased uptake of Fe by maize plant at all the levels of application of wastes, except at 44 t ha⁻¹ of application of GSW where it increased significantly over control. It ranged from 7.8 (GSW 11 t ha⁻¹) to 36.78 mg pot⁻¹ (GSW 44 t ha⁻¹).

The manganese uptake was also significantly decreased in treatments with FYM 44, ASW 11 and GFW 44 t ha⁻¹. In some treatments the uptake of Mn was increased significantly. The mean Mn uptake of maize plant ranged from 0.5 (FYM 44 t ha⁻¹) to 3.45 mg pot⁻¹ (GSW 22 t ha⁻¹).

Application of ASW and GFW increased mean Zn uptake by maize at all levels of waste application significantly as compared to control, except in ASW 11 t ha⁻¹ treatment. Whereas FYM and GSW significantly increa-

Table 51 : Effect of organic wastes application on uptake of micronutrients by maize plant (mg pot⁻¹)

=====				
Organic manures				
t ha ⁻¹	Fe	Mn	Zn	Cu

FYM				
0	15.43	1.52	1.39	0.78
11	14.18	1.53	1.33	0.21
22	14.71	1.53	2.32	2.42
33	19.20	3.03	1.39	0.23
44	10.65	0.50	1.50	0.40
ASW				
0	16.08	1.53	1.31	0.81
11	12.42	0.56	1.30	0.70
22	15.77	1.91	2.02	1.20
33	14.01	2.13	2.39	0.60
44	11.33	2.45	1.90	1.28
GSW				
0	17.30	1.78	1.57	0.87
11	7.80	2.17	1.31	0.19
22	12.24	3.45	1.55	0.08
33	11.41	1.03	2.79	0.31
44	36.78	1.91	2.43	0.52
GFW				
0	13.79	1.35	1.37	0.69
11	11.04	2.90	2.50	1.27
22	14.27	3.26	2.82	0.80
33	9.58	1.79	1.72	0.11
44	10.44	0.73	1.90	0.57
SEd ±	2.127	0.247	0.173	0.300
L.S.D.(0.05)	4.258	0.495	0.347	0.602
=====				

ASW - Amberpet stabilized waste
 GSW - Golkonda stabilized waste
 GFW - Golkonda fresh waste

sed mean Zn uptake at 22 t ha⁻¹ and 33 and 44 t ha⁻¹ levels respectively over controls. It ranged from 1.30 (ASW 11 t ha⁻¹) to 2.82 mg pot⁻¹ (GFW 22 t ha⁻¹).

The mean copper uptake increased significantly with FYM when applied at 22 t ha⁻¹ only whereas it decreased significantly with GSW at 22 t ha⁻¹ over control. It ranged from 0.08 (GSW at 22 t ha⁻¹) to 2.42 mg pot⁻¹ (FYM at 22 t ha⁻¹). There was no consistence in the uptake of Cu by maize among the treatments.

4.6.2.2 Heave metals uptake: The data on heavy metal uptake are presented in Table 52.

The data reveal that the mean lead uptake by maize increased significantly over control in almost all the treatments with some exceptions. It ranged from 42 (GFW control) to 913 ug pot⁻¹ (GFW 33 t ha⁻¹).

The nickel uptake also increased significantly over control with some exceptions. It ranged from 3.9 (FYM and GFW control) to 89.5 ug pot⁻¹ (ASW 22 t ha⁻¹).

The significant increase in uptake of mean cobalt was observed in all the treatments over control whereas, it could not be detected in control and with FYM 11 and 22 t ha⁻¹ treatments. It ranged from not detectable to 12.1 ug pot⁻¹ (GSW 44 t ha⁻¹).

Table 52 : Effect of organic wastes application on uptake of heavy metals by maize plant (ug pot⁻¹)

=====					
Organic manures	Pb	Ni	Co	Cd	Cr
t ha ⁻¹					

FYM					
0	47.00	3.90	ND	ND	ND
11	61.00	11.00	ND	ND	ND
22	71.00	10.00	ND	ND	ND
33	105.00	8.00	4.00	ND	ND
44	235.00	10.00	7.00	ND	ND
ASW					
0	56.00	5.90	ND	ND	ND
11	68.00	15.50	4.30	ND	ND
22	172.00	89.50	5.70	ND	ND
33	220.00	37.00	7.00	ND	ND
44	876.00	17.90	9.00	ND	7.6
GSW					
0	56.00	6.60	ND	ND	ND
11	314.00	15.00	6.40	ND	ND
22	746.00	14.00	9.50	ND	ND
33	874.00	16.00	10.00	ND	ND
44	786.00	9.00	12.10	ND	12.0
GFW					
0	42.00	3.90	ND	ND	ND
11	255.00	54.00	ND	ND	ND
22	447.00	77.00	4.60	ND	ND
33	913.00	34.00	5.30	ND	8.2
44	859.00	20.00	6.70	ND	8.0
SEd +	26.21	2.317	0.785	--	--
L.S.D.(0.05)	52.47	4.640	1.572	--	--
=====					

ASW - Amberpet stabilized waste
 GSW - Golkonda stabilized waste
 GFW - Golkonda fresh waste

ND - Not detected

The cadmium uptake of maize with USW or FYM was not affected by any of the treatments.

Similarly the chromium uptake was also not detected, with the exception to ASW 44 and GFW 33 and 44 t ha⁻¹ and GSW 44 t ha⁻¹ treatments. It ranged from 7.6 (ASW 44 t ha⁻¹) to 12.0 ug pot⁻¹ (GSW 44 t ha⁻¹).

The pattern of uptake of micronutrients and heavy metals by maize plant quantitatively followed the order of Fe > Mn > Zn > Cu > Pb > Ni > Co > Cr and Cd irrespective of treatments employed in the study.

4.6.3 Effect of urban solid wastes and FYM on micro-nutrient and heavy metal contents in maize plant parts

The data are presented in Table 53 and 54.

4.6.3.1 Iron: The mean concentration of iron content in roots decreased significantly in all the treatments when compared with control with some exceptions. It ranged from 1182 (ASW 33 t ha⁻¹) to 3667 ppm (ASW 11 t ha⁻¹).

In stem the mean content of iron decreased significantly in all the treatments over control. It ranged from 52.0 (GSW 22 t ha⁻¹) to 330.0 ppm (GSW control).

The mean iron content in leaf varied significantly in some treatments. It ranged from 121.5 (FYM 22 t ha⁻¹) to 678.0 ppm (FYM 33 t ha⁻¹).

In general, the application of wastes significantly decreased Fe content in roots and stems of maize plant, whereas significant increase was observed in leaves of maize with some exceptions.

Symptomatic deficiency of Fe was not recorded in the maize plants at the time of harvest because the leaf content of iron is above the critical level (i.e., 15 ppm). The pattern of distribution of iron followed the order of root > leaf > stem.

4.6.3.2 Manganese: The mean concentration of manganese in maize roots increased in all the treatments but significant increase was observed only in some treatments. It ranged from 30.5 (ASW 33 t ha⁻¹) to 110.0 ppm (ASW 11 t ha⁻¹).

In the stem, the mean manganese content increased significantly in most of the treatments. It ranged from 4.3 (ASW control) to 56.0 ppm (GSW 22 t ha⁻¹).

In leaf, the mean content of manganese decreased significantly in all the treatments over control with two exceptions viz., ASW 44 and GFW 22 t ha⁻¹ where it increased significantly. It ranged from 5.0 (ASW 11 t ha⁻¹) to 115.0 ppm (GFW 22 t ha⁻¹).

However, the deficiency was not apparent in the maize plant at the time of harvest as the leaf manganese content was above the critical level (i.e., 15 ppm) whereas in ASW 11 t ha⁻¹ treatment, the leaf Mn content was found to be 5 ppm.

In general, manganese content increased in root, stem and decreased in leaf, irrespective of the treatments studied.

Overall pattern of distribution of Mn in maize plant parts followed the order of root > leaf > stem with some exceptions.

4.6.3.3 Zinc: The mean zinc content in root did not show any clear trend due to soil application of USW or FYM. It ranged from 21 (GSW 22 t ha⁻¹) to 133 ppm (ASW 33 t ha⁻¹) and decreased significantly with FYM application 11 and 22 t ha⁻¹ whereas it increased significantly with FYM 33 t ha⁻¹, ASW 11, 33 and 44 t ha⁻¹ treatments over control.

In stem, the mean zinc content increased significantly in all the treatments with some exceptions. It ranged from 10.7 (FYM 11 t ha⁻¹) to 35.0 ppm (ASW 22 t ha⁻¹).

In leaf the mean zinc content increased in most of the treatments significantly. It ranged from 25.0 (GSW 22 t ha⁻¹) to 86.0 ppm (GSW 11 t ha⁻¹).

However, Zn deficiency or toxicity symptoms were not observed in the maize plant at the time of harvest as the leaf content of Zn is above critical level (i.e. 10 ppm).

In general, zinc content in roots and leaves did not show any clear trend whereas an increase in stem Zn content were observed over control.

To generalise, the pattern of distribution of Zn content in plant parts followed the order : leaf > root > stem.

4.6.3.4 Copper: The mean copper content of the roots showed significant increase or decrease over control in some treatments. It ranged from 3.0 (FYM 33 t ha⁻¹) to 38.5 ppm (GFW 44 t ha⁻¹). It did not show any clear trend in changes due to application of organic wastes to maize.

In stem, the copper content was decreased significantly in all the treatments, with two exceptions, where it increased significantly. It ranged from 0.60 (ASW 44 t ha⁻¹) to 37.0 ppm (FYM 22 t ha⁻¹).

In leaf, the mean copper content did not show any clear trend with change in treatments. However, it significantly increased or decreased in some treatments over control. It ranged from 2.2 (GSW 22 and GFW 11

Table 53 : Effect of organic wastes application on concentration of micronutrients in maize plant parts

Organic manure t ha ⁻¹	Iron			Manganese			Zinc			Copper		
	Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf
FYM	ppm											
0	2521.00	326.00	288.00	40.00	5.00	75.00	33.00	18.60	45.00	9.20	17.00	13.70
11	1586.00	204.00	373.00	40.00	16.40	50.00	22.00	10.70	50.00	8.00	2.10	7.40
22	1691.00	282.00	121.50	70.00	22.10	25.00	25.00	33.50	39.00	15.40	37.00	36.00
33	1356.00	74.00	678.00	50.00	33.50	70.00	44.00	19.00	26.00	3.00	1.80	6.80
44	2429.00	126.00	282.00	45.00	5.00	15.00	26.00	19.00	38.00	15.30	8.20	5.50
ASW												
0	2485.00	316.00	290.00	38.00	4.30	72.00	29.00	16.50	40.00	8.60	16.40	13.10
11	3667.00	156.00	434.00	110.00	16.00	5.00	58.40	17.00	45.00	18.10	8.50	25.50
22	2205.00	243.00	391.00	63.00	28.00	50.00	39.00	35.00	44.00	7.50	31.70	8.00
33	1182.00	74.00	478.00	30.50	33.50	35.00	133.00	25.00	61.00	6.10	11.30	6.90
44	1226.00	61.00	468.00	36.00	20.00	90.00	84.00	12.00	76.00	19.70	0.60	64.00
GSW												
0	2510.00	330.00	281.00	42.00	5.20	78.00	31.00	17.10	48.00	9.50	17.10	14.10
11	2376.00	69.00	227.00	58.00	39.00	30.00	23.00	15.00	33.00	5.70	1.90	5.30
22	2283.00	52.00	388.00	74.00	56.00	40.00	31.00	21.00	25.00	12.50	0.85	2.20
33	3014.00	147.25	227.00	74.00	5.00	35.00	37.70	30.50	65.00	11.40	4.40	6.10
44	1382.00	187.00	360.00	36.00	22.00	50.00	26.10	32.00	57.00	9.10	8.70	9.30
GFW												
0	2530.00	320.00	284.00	37.00	5.10	73.00	30.00	18.40	51.00	9.00	16.80	13.40
11	1452.00	65.00	484.00	41.00	50.70	70.00	35.00	29.00	86.00	5.00	10.70	2.20
22	1521.00	104.00	488.00	40.00	22.00	115.00	21.00	28.00	84.00	5.40	9.80	21.00
33	1860.00	165.00	155.00	45.00	39.00	15.00	25.00	21.00	43.00	9.20	1.10	3.47
44	2626.00	78.00	413.00	65.00	5.00	30.00	22.75	18.50	68.00	38.50	5.20	21.80
SEd +	30.148	11.02	9.513	4.95	1.44	3.995	5.726	1.288	2.674	0.803	0.768	0.837
L.S.D. (0.05)	60.356	22.06	19.04	9.92	2.89	7.998	11.465	2.580	5.354	1.609	1.537	1.677

ASW - Amberpet stabilized waste

GSW - Golkonda stabilized waste

GFW - Golkonda fresh waste

t ha⁻¹) to 36.0 ppm (FYM 22 t ha⁻¹). In some treatments, the Cu content in leaf was below the critical level of 5 ppm at harvest.

In general, the mean copper content in root and leaf did not follow any clear trend, whereas it decreased significantly in stem with some exceptions. The content of Cu in maize plant parts followed the order stem > leaf > root.

4.6.3.5 Lead : The data pertaining to lead content in maize plant are presented in Table 54.

The mean Pb content in maize plant roots increased significantly in all the treatments except with FYM at all levels of application. The Pb content ranged from 0.40 (control) to 173.0 ppm (ASW 44 t ha⁻¹).

Similarly Pb content in stem also increased significantly in all the treatments except with FYM treatments. It ranged from 0.14 (GFW control) to 25.0 ppm (GFW 44 t ha⁻¹).

In leaves, the lead content increased significantly over control in all the treatments except with FYM. It ranged from 0.01 (FYM control) to 7.0 ppm (ASW 44 t ha⁻¹).

In general, Pb content in all the plant parts increased significantly over control with all the treatments except with FYM.

The pattern of distribution of Pb content in maize plant parts followed the order : root > stem > leaf.

4.6.3.6 Nickel: The mean nickel content in root increased significantly in all the treatments when compared to respective controls. It ranged from 0.30 (FYM control) to 4.8 ppm (GSW 22 t ha⁻¹). The increase in root nickel content was not following any specific trend with the application of organic wastes to maize.

In stem, the mean nickel content increased significantly in different treatments, with some exceptions. It ranged from 0.11 (GFW control) to 2.6 ppm (ASW 22 t ha⁻¹).

The mean nickel content of leaf increased significantly in all the treatments with some exceptions. It ranged from 0.05 (GSW control) to 0.9 ppm (GFW 11 t ha⁻¹).

In general, the nickel content increased in root, stem and leaf in all the treatments but not linearly with the level of application of GSW. The pattern of nickel content in different plant parts followed the order : root > stem > leaf.

4.6.3.7 Cobalt: The mean cobalt content of roots increased significantly in all the treatments. It ranged from 0.11 (FYM control) to 0.31 ppm (GSW 33 t ha⁻¹).

The mean content of cobalt in stem increased significantly in the treatments with some exceptions, where it was not detected at all. In all the control treatments too the cobalt could not be detected. It ranged from traces to 0.28 ppm (GSW 44 t ha⁻¹).

In leaf, the content of cobalt followed similar pattern as that of stem. It ranged from traces to 0.15 ppm (GSW 33 t ha⁻¹).

In general, the content of cobalt in root, stem and leaf with all the treatments increased significantly over control. The cobalt content followed the order : root > stem > leaf and was found to be within limits of cobalt content reported elsewhere for maize.

4.6.3.8 Chromium and cadmium: The chromium content of root varied from not detectable to 5.6 (GSW 44 t ha⁻¹) ppm. Only at higher levels of waste application i.e., 33 and 44 t ha⁻¹, chromium content in root was detected and in FYM treatment, chromium content was not detected at all the levels of its application.

In stem the chromium content varied from traces to 0.3 ppm (GSW 44 t ha⁻¹). The urban waste application at 44 t ha⁻¹ resulted in increase in chromium content of

Table 54 : Effect of organic wastes application on concentration of heavy metals in maize plant parts

Organic manure t ha ⁻¹	Lead			Nickel			Cobalt			Chromium			Cadmium		
	Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf
FYM	ppm														
0	0.40	0.15	0.010	0.300	0.12	0.054	0.11	ND	ND	ND	ND	ND	ND	ND	ND
11	1.68	0.80	0.010	1.325	0.30	0.100	0.14	ND	ND	ND	ND	ND	ND	ND	ND
22	1.84	0.90	0.020	1.500	0.20	0.100	0.10	ND	ND	ND	ND	ND	ND	ND	ND
33	2.10	1.00	0.025	2.900	0.10	0.200	0.20	0.10	ND	ND	ND	ND	ND	ND	ND
44	2.40	1.20	0.027	3.600	0.18	0.200	0.24	0.18	0.06	ND	ND	ND	ND	ND	ND
ASW															
0	0.45	0.16	0.020	0.400	0.15	0.056	0.12	ND	ND	ND	ND	ND	ND	ND	ND
11	26.30	1.40	1.500	9.900	0.40	0.200	0.21	0.12	0.04	ND	ND	ND	ND	ND	ND
22	12.80	4.00	2.000	1.900	2.60	0.180	0.24	0.14	0.06	ND	ND	ND	ND	ND	ND
33	22.50	5.00	1.000	2.900	0.50	0.800	0.23	0.13	0.09	3.00	ND	ND	ND	ND	ND
44	173.0	21.90	7.000	2.200	0.50	0.100	0.30	0.23	0.10	4.50	0.20	0.05	ND	ND	ND
GSW															
0	0.40	0.15	0.015	0.450	0.16	0.051	0.12	ND	ND	ND	ND	ND	ND	ND	ND
11	23.00	6.70	2.500	3.770	0.30	0.180	0.21	0.12	0.08	1.00	ND	ND	ND	ND	ND
22	72.70	15.40	2.800	4.800	0.30	0.120	0.25	0.15	0.12	2.10	ND	ND	ND	ND	ND
33	6.18	19.30	3.800	4.200	0.30	0.200	0.31	0.16	0.15	4.50	ND	ND	ND	ND	ND
44	15.50	20.20	1.500	2.000	0.20	0.100	0.30	0.28	0.10	3.90	0.30	0.05	ND	ND	ND
GFW															
0	0.45	0.14	0.020	0.400	0.11	0.053	0.13	ND	ND	ND	ND	ND	ND	ND	ND
11	2.50	6.90	2.000	1.500	1.10	0.900	0.18	ND	ND	ND	ND	ND	ND	ND	ND
22	32.20	10.80	2.500	4.100	1.80	0.500	0.21	0.10	0.05	ND	ND	ND	ND	ND	ND
33	24.00	24.00	2.000	2.200	0.70	0.400	0.26	0.12	0.06	1.00	0.20	0.04	ND	ND	ND
44	26.80	25.00	1.600	2.600	0.60	0.050	0.22	0.16	0.07	5.60	0.22	0.05	ND	ND	ND
SEd +	0.921	0.60	0.121	0.390	0.063	0.0368	0.011	0.011	0.0071	--	--	--	--	--	--
L.S.D. (0.05)	1.844	1.20	0.244	0.781	0.128	0.0730	0.023	0.022	0.0143	--	--	--	--	--	--

ASW - Amberpet stabilized waste
 GSW - Golkonda stabilized waste
 GFW - Golkonda fresh waste

ND - Not detected

stem whereas FYM application did not lead to any such effect.

The chromium content in leaf followed a pattern similar to that of stem. It ranged from traces to 0.05 ppm.

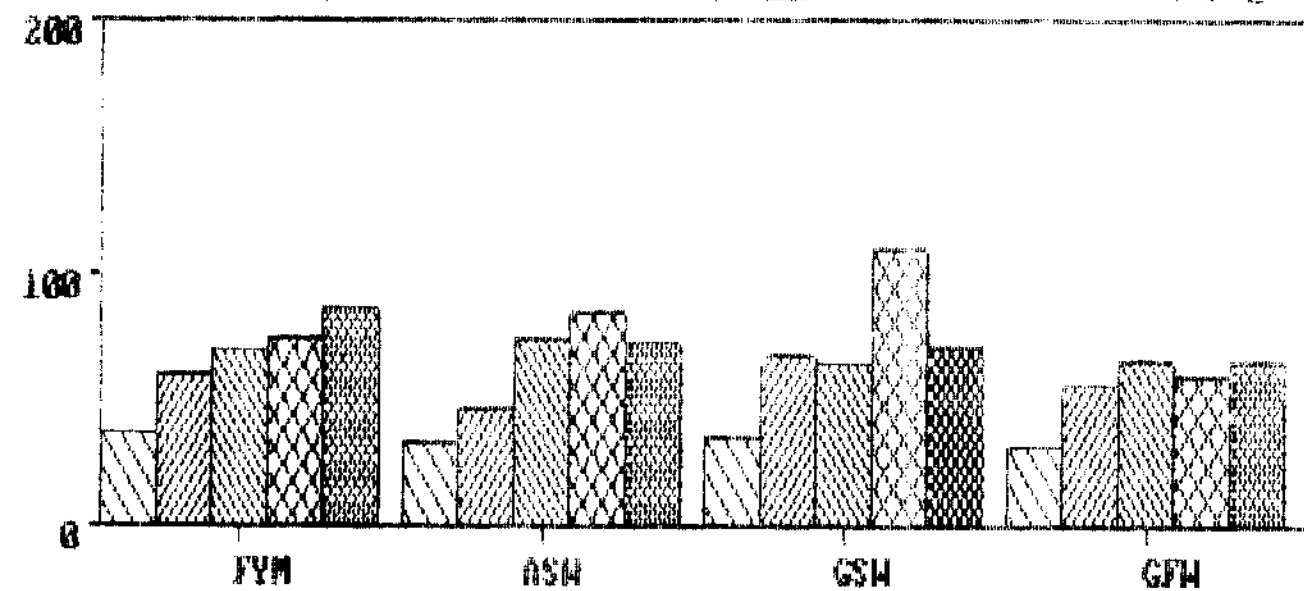
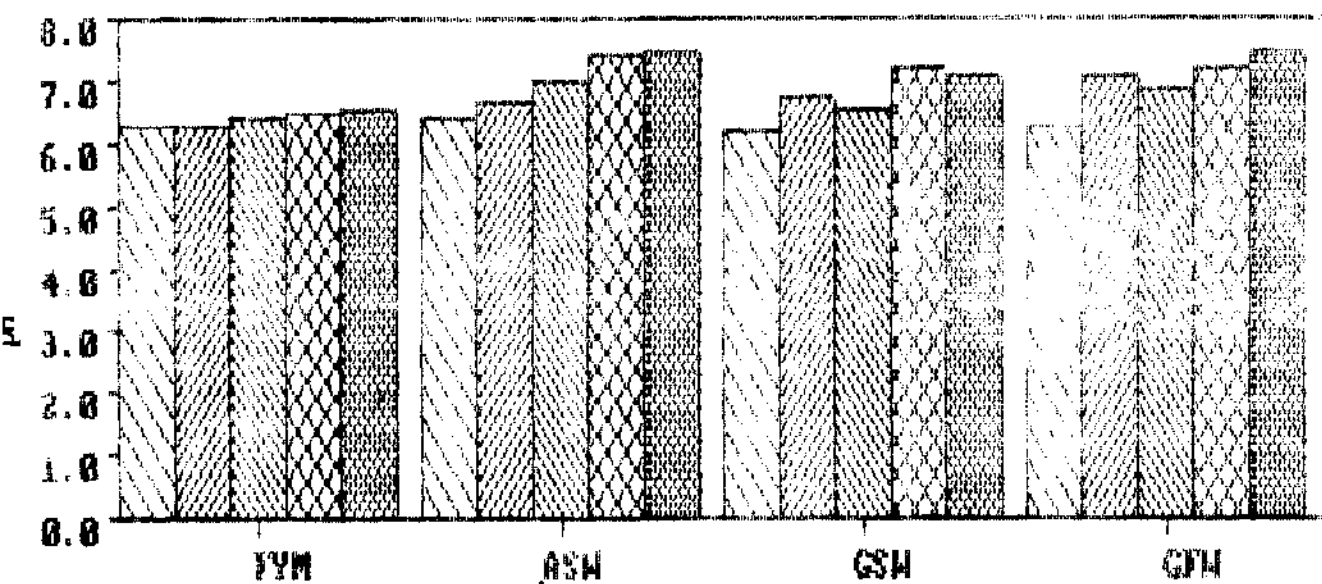
In general, the waste application did not result in increase in chromium content in plant parts. Cadmium was not detected in any of the plant parts at all the levels of waste application.

4.6.4 Effect of urban solid wastes and FYM on some soil properties

To ascertain the effect of different levels of application of raw or stabilized urban solid wastes and FYM on some soil properties, the soil samples collected from different treatments after harvest of maize were analysed.

4.6.4.1 Soil reaction (pH): The soil pH increased significantly in all the treatments as compared to respective controls. It ranged from 6.2 (GSW control) to 7.5 (ASW and GFW 44 t ha⁻¹) (Fig. 13).

4.6.4.2 Electrical conductivity (EC): The electrical conductivity of soil increased significantly in all the USW and FYM treatments as compared to respective controls. It ranged from 33.0 (GFW control) to 111.0 μ S



Organic Wastes

0.0 11.0 22.0 33.0 44.0 (t ha⁻¹)

Fig. 13 Soil PH and EC as affected by application of USW and FYM

m^{-1} (GSW 33 t ha^{-1}). However, there was no clear trend obtained due to application of USW or FYM (Fig. 13).

4.6.4.3 DTPA-extractable micronutrients: The data are presented in Table 55.

All the treatments increased significantly available Fe content, except one (GFW 22 t ha^{-1}) over control. It ranged from 5.8 (GFW 22 t ha^{-1}) to 14.6 ppm (FYM 22 t ha^{-1}).

The available Mn content decreased significantly in some treatments when compared with control. All the FYM treatments, except the highest level used (44 t ha^{-1}), significantly increased DTPA Mn as compared to control. It ranged from 8.0 (GSW 33 t ha^{-1}) to 16.25 (FYM 11 t ha^{-1}) ppm. The DTPA Mn did not show any specific trend with the application of different levels of organic wastes to soil.

The mean available Zn content of all the treatments increased significantly when compared with controls. It ranged from 0.8 (GSW control) to 4.4 (GSW 33 t ha^{-1}) ppm. Generally the levels of application of wastes increased the mean available Zn content but the trend was not spectacular in some treatments.

Similarly, the mean available Cu content was also increased significantly with all the waste treat-

**Table 55 : Effect of organic wastes application on DTPA
- extractable micronutrients in soil**

=====				
Organic manures	Fe	Mn	Zn	Cu
t ha ⁻¹				

FYM	-----ppm-----			
0	8.00	11.00	1.00	0.49
11	10.60	16.25	1.66	0.50
22	14.60	14.80	2.00	0.48
33	8.60	12.60	2.00	0.53
44	10.60	10.00	2.40	0.61
ASW				
0	7.87	10.80	0.90	0.50
11	11.20	10.00	2.50	0.77
22	11.40	10.60	2.50	0.73
33	12.10	9.20	3.10	0.95
44	12.20	9.40	3.00	0.99
GSW				
0	7.80	10.70	0.80	0.54
11	14.20	11.40	2.40	1.27
22	13.40	11.00	2.10	0.83
33	12.80	8.00	4.40	2.40
44	9.00	9.20	2.20	0.90
GFW				
0	8.00	11.00	0.90	0.53
11	8.30	10.40	2.00	0.60
22	5.80	10.80	2.25	0.60
33	8.80	10.40	2.40	0.70
44	11.20	9.80	1.80	0.50
SEd +	0.143	0.382	0.125	0.030
L.S.D.(0.05)	0.280	0.766	0.251	0.070

=====

ASW - Amberpet stabilized waste
GSW - Golkonda stabilized waste
GFW - Golkonda fresh waste

ments when compared with control except with FYM treatments where only 44 t ha^{-1} level showed significant increase over control. It ranged from 0.49 (FYM control) to 2.4 ppm (GSW 33 t ha^{-1}).

In general, application of organic wastes increased significantly DTPA extractable Fe, Zn and Cu of soil at all the levels and significantly decreased Mn content in most of the treatments.

4.6.4.4 DTPA-extractable heavy metals: The data are presented in Table 56.

The mean DTPA-extractable Pb content increased significantly in all the waste treatments when compared with control. It ranged from 0.03 (ASW and GFW control) to 6.2 ppm (ASW 44 t ha^{-1}). However, with FYM application such an increase in Pb content was not noticed.

The mean DTPA Ni increased due to addition of wastes and FYM at all levels, but significant increases were observed only in some treatments. It ranged from 0.008 (GSW control) to 0.17 ppm (ASW 22 t ha^{-1}).

Application of wastes and FYM increased DTPA Co significantly at all levels of application and ranged from 0.03 (ASW and GFW control) to 0.15 ppm (ASW 11 t ha^{-1}), but the increase did not show relationship with the level of application of urban wastes and FYM.

Table 56 : Effect of organic wastes application on DTPA
- extractable heavy metals in soil

=====					
Organic manures					
t ha ⁻¹	Pb	Ni	Co	Cd	Cr

FYM	-----ppm-----				
0	0.04	0.010	0.04	ND	ND
11	0.05	0.010	0.08	ND	ND
22	0.05	0.020	0.06	ND	ND
33	0.06	0.080	0.08	ND	ND
44	0.07	0.080	0.08	ND	ND
ASW					
0	0.03	0.010	0.03	ND	ND
11	3.40	0.110	0.15	0.01	ND
22	2.90	0.170	0.06	0.01	ND
33	3.80	0.140	0.08	0.02	ND
44	6.20	0.050	0.08	0.06	ND
GSW					
0	0.04	0.009	0.04	ND	ND
11	4.00	0.120	0.08	0.03	ND
22	4.70	0.050	0.06	0.04	ND
33	2.87	0.080	0.08	0.08	ND
44	2.30	0.030	0.08	0.09	ND
GFW					
0	0.03	0.008	0.03	ND	ND
11	2.77	0.010	0.08	0.04	ND
22	3.80	0.070	0.14	0.07	ND
33	3.00	0.029	0.06	0.08	ND
44	3.10	0.130	0.08	0.08	ND
SEd +	0.118	0.0128	0.0059	0.0021	
L.S.D.(0.05)	0.238	0.025	0.011	0.0043	
=====					

ASW - Amberpet stabilized waste
GSW - Golkonda stabilized waste
GFW - Golkonda fresh waste

ND - Not detected

Application of municipal solid wastes only increased mean DTPA-extractable Cd significantly in all the treatments while in all the controls and in FYM treatments the DTPA-Cd was not detected. The content of Cd ranged from traces to 0.09 ppm (GSW 44 t ha⁻¹).

The DTPA-extractable Cr content was not detected in any of the treatments studied including controls. The mean DTPA micronutrient and heavy metal content in soil after harvest of the maize crop followed the order : Fe > Mn > Zn > Pb > Cu > Ni > Co > Cd > Cr with few exceptions.

4.6.4.5 Total micronutrients

The data pertaining to total micronutrient and heavy metal contents in soil after harvest of the maize crop are presented in Tables 57 and 58.

The total iron content of soil in all the treatments increased significantly over control. It ranged from 2790 (GFW control) to 4150 ppm (GFW 44 t ha⁻¹).

The total manganese content of soil in all the treatments was more when compared to control. It ranged from 160 (FYM control) to 192 ppm (GFW 22 t ha⁻¹).

Total Zn content of soil in all the treatments increased significantly over control. It ranged from 6.9 (GFW control) to 27.10 ppm (ASW 44 t ha⁻¹).

Table 57 : Effect of organic wastes application on total ($\text{HNO}_3 + \text{HClO}_4$) micronutrients in soil

=====				
Organic manures				
t ha ⁻¹	Fe	Mn	Zn	Cu

FYM	----- ppm -----			
0	2800.00	160.00	7.00	0.90
11	3130.00	190.00	8.30	1.60
22	3120.00	185.00	12.60	2.50
33	3970.00	180.00	11.90	2.30
44	3440.00	170.00	13.70	2.10
ASW				
0	2811.00	166.00	7.20	1.00
11	3930.00	190.00	12.50	4.00
22	3520.00	184.00	13.10	3.60
33	3680.00	189.00	14.40	4.80
44	4090.00	183.00	27.10	5.20
GSW				
0	2809.00	161.00	7.30	0.95
11	3560.00	170.00	9.80	4.60
22	3410.00	183.00	13.50	4.60
33	3060.00	188.00	12.10	6.10
44	3570.00	180.00	14.40	6.70
GFW				
0	2790.00	165.00	6.90	1.00
11	3770.00	180.00	10.30	2.90
22	4130.00	192.00	11.60	2.80
33	3890.00	180.00	14.80	3.10
44	4150.00	180.00	22.90	3.60
SEd ±	55.10	7.06	0.245	0.202
L.S.D.(0.05)	110.31	14.14	0.492	0.404
=====				

ASW - Amberpet stabilized waste
 GSW - Golkonda stabilized waste
 GFW - Golkonda fresh waste

Similarly total Cu content of soil increased in all the treatments significantly over control. It ranged from 0.9 (FYM control) to 6.7 ppm (GSW 44 t ha⁻¹).

In general, the total content of Fe, Mn, Zn and Cu increased significantly with the application of wastes USW or FYM over control soil.

4.6.4.6 Total heavy metals: The total lead content of soil in all the treatments, except with FYM, increased significantly over control. With FYM treatment, only at 44 t ha⁻¹ level, the soil lead content showed significant increase over control. It ranged from 5.9 (GFW control) to 54.0 ppm (GFW 22 t ha⁻¹).

The Ni content also increased significantly at all the levels of application of USW. The mean total Ni content of soil ranged from 2.0 (FYM control) to 7.5 ppm (GSW 44 t ha⁻¹).

The total cobalt content in soil increased significantly at all the levels of treatment and it ranged from 2.3 (GFW control) to 6.0 ppm (GFW 22 t ha⁻¹).

The total cadmium content in soil of all the treatments increased significantly over control, except with FYM treatments. It ranged from 0.37 (FYM control) to 1.06 ppm (ASW 44 t ha⁻¹).

Table 58 : Effect of organic wastes application on total
(HNO₃ + HClO₄) heavy metals in soil

Organic manures t ha ⁻¹	Pb	Ni	Co	Cd	Cr
FYM	-----ppm-----				
0	6.00	2.00	2.60	0.37	10.10
11	6.50	2.30	3.00	0.40	11.50
22	7.00	2.80	3.20	0.42	11.25
33	7.60	2.80	3.50	0.43	11.00
44	7.80	2.70	3.60	0.42	11.00
ASW					
0	6.00	2.20	2.50	0.38	10.20
11	25.00	3.00	3.00	0.70	18.60
22	31.00	4.00	3.30	0.80	27.10
33	10.00	4.50	3.50	0.95	27.00
44	12.00	3.20	4.00	1.06	25.25
GSW					
0	5.95	2.10	2.40	0.40	10.30
11	12.00	3.50	3.00	0.60	20.00
22	32.00	5.70	5.00	0.62	23.00
33	24.00	6.80	4.50	0.70	21.00
44	29.00	7.50	4.00	0.82	18.00
GFW					
0	5.90	2.20	2.30	0.41	10.00
11	20.00	3.50	4.00	0.70	20.00
22	54.00	4.20	6.00	0.80	22.00
33	29.00	4.80	4.40	0.85	25.00
44	47.00	5.70	4.00	0.90	19.00
SEd +	0.878	0.108	0.098	0.035	0.835
L.S.D.(0.05)	1.758	0.217	0.197	0.070	1.670

ASW - Amberpet stabilized waste
GSW - Golkonda stabilized waste
GFW - Golkonda fresh waste

The total chromium content in soil of all the treatments increased significantly as that of Cd. It ranged from 10.0 (GFW control) to 27.0 ppm (ASW 33 t ha⁻¹).

In general, application of organic wastes to a red chalka soil increased total heavy metal contents of soil over control.

The total micronutrients and heavy metals build up due to various treatments followed the order: Fe > Mn > Pb > Cr > Zn > Cu > Ni > Co > Cd with few exceptions.

4.7 EFFECT OF APPLICATION OF RAW URBAN SOLID WASTES ON SOIL PROPERTIES AND UPTAKE OF MICRONUTRIENTS AND HEAVY METALS BY SOME PLANT SPECIES

It is a common practice in areas around Hyderabad City to use directly the urban solid wastes as a resource for building up soil organic matter and supply plant nutrients. To study the impact of such a practice on soil properties and uptake of micronutrients and heavy metals by crops, a preliminary survey was conducted to identify the locations, where farmers are using urban solid wastes directly as a source of manure for cultivating crops. These locations were so chosen as to get samples of cereal crops, millets and vegetables. Detailed analysis of soils was made and the distribution of micronutrients and heavy metals in different parts of

plants obtained from locations, where USW are being used as manures, were determined. The results are detailed here.

(A) Effect on soil properties

(B) Distribution of micronutrients and heavy metals in plant parts

4.7.1 Physical, physico-chemical and chemical properties of soils treated with USW

4.7.1.1 Physical

a) Particle size distribution: The data are presented in Table 59.

The mean sand content of soils collected from sites 1 to 6 decreased as compared to control. It ranged from 39.50 (site 1) to 80.5 per cent (site 7). In all the sites at both the depths, the sand contents varied from 37.0 (0-15 cm) in site 1 to 81.0 per cent (0-15 cm) in site 7.

In contrast, the mean silt content of soils of all the sites, except two (site 3 and 7) showed increase over control. It varied from 9.8 (control) to 32.5 per cent (site 1). In all the sites, silt content ranged from 9.0 (15-30 cm) in control site to 33.0 per cent (15-30 cm) in site 1.

Table 59 : Particle size distribution and texture of soils treated with urban solid wastes

Location	Depth cm			Sand (%)			Silt (%)			Clay (%)			Soil textural class (USDA)	
	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30
Site-1	37.0	42.0	39.5	32.0	33.0	32.5	31.0	25.0	28.0	31.0	25.0	28.0	1	1
Site-2	65.0	61.0	63.0	14.0	14.0	14.0	21.0	25.0	23.0	21.0	25.0	23.0	scl	scl
Site-3	71.0	67.0	69.0	10.0	14.0	12.0	19.0	19.0	19.0	19.0	19.0	19.0	sl	sl
Site-4	56.0	54.0	55.0	16.0	20.0	18.0	28.0	26.0	27.0	28.0	26.0	27.0	scl	scl
Site-5	59.6	63.6	61.6	32.0	28.0	30.0	8.4	8.4	8.4	8.4	8.4	8.4	sl	sl
Site-6	75.6	67.6	71.6	12.0	20.0	16.0	12.4	12.4	12.4	12.4	12.4	12.4	sl	sl
Site-7	81.0	80.0	80.5	12.0	11.0	11.5	7.0	9.0	8.0	7.0	9.0	8.0	ls	ls
Control site	80.4	76.0	78.2	10.6	9.0	9.8	9.0	15.0	12.0	9.0	15.0	12.0	ls	ls

1 = loam scl = sandy clay loam sl = sandy loam ls = loamy sand

Similarly, the mean clay contents of soils from sites 1 to 4 showed increase over control. The clay content ranged from 8.0 (site 7) to 28.0 per cent (site 1). In all the sites, at both the depths, the clay contents ranged from 7.0 (0-15 cm) in site 7 to 31.0 per cent (0-15 cm) in site 1.

b) Textural class (U.S.D.A.): According to U.S.D.A. soil textural classification, the soil of sites 1 to 8 (including control) varied from sandy clay loam to loamy sands.

4.7.1.2 Physico-chemical properties: The data are presented in Table 60.

a) Soil reaction (pH): The mean soil pH of sites varied from 6.1 (control site) to 8.5 (site 6). It was more in all the sites than control. In all the sites at both the depths, the pH values varied from 6.0 (0-15 cm) in control to 8.5 (15-30 cm) in site 6 (Fig. 14).

b) Electrical conductivity (EC): The mean electrical conductivity of soils ranged from 0.045 (control) to 1.85 d S m⁻¹ (site 4). The increase in mean EC values was noticed in soils from all the sites as compared to control. In all the sites, at both the depths, the EC values ranged from 0.04 (0-15 cm) in control to 2.50 d S m⁻¹ (0-30 cm) in site 4 (Fig. 14).

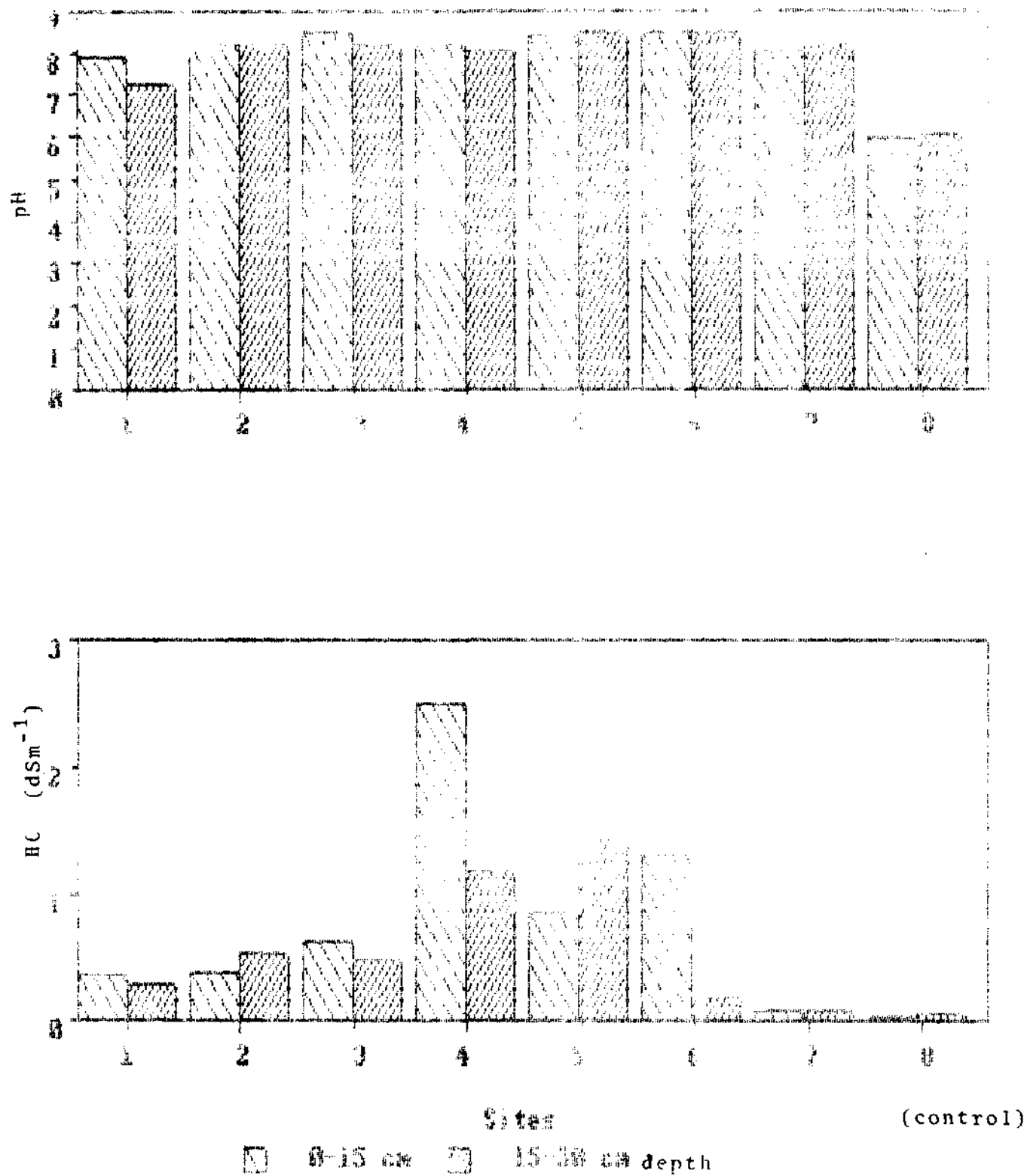


Fig. 14 Soil PH and EC as affected by the application of USW in farmers fields

c) **Cation exchange capacity (CEC):** The mean CEC of soils from all the sites showed increase over control. It ranged from 8.90 (site 6) to 31.55 Cmol (P⁺) kg⁻¹ soil (site 4). In all the sites, at both the depths, the CEC values ranged from 6.85 (0-15 cm) in control site to 33.0 Cmol (P⁺) kg⁻¹ (0-15 cm) in site 4 (Fig.15).

d) **Exchangeable cations**

Calcium: The mean exchangeable calcium content of soils from all the sites showed increase over control, with exception of sites 5 and 6, where it decreased over control. It ranged from 3.5 (site 6) to 18.10 Cmol (P⁺) kg⁻¹ soil (site 4). In all the sites, at both the depths, the exchangeable calcium content ranged from 3.3 (15-30 cm) in site 6 to 18.7 Cmol (P⁺) kg⁻¹ soil (15-30 cm) in in site 4.

Magnesium: The mean exchangeable magnesium content of soils from all the sites showed increase over control. It ranged from 2.12 (control) to 6.35 Cmol (P⁺) kg⁻¹ soil (site 1). In all the sites at both the depths, the magnesium contents ranged from 1.5 (0-15 cm) in control to 7.25 Cmol (P⁺) kg⁻¹ soil (0-15 cm) in site 1.

Potassium: The mean exchangeable potassium content of soils from all the sites showed increase over control. It ranged from 0.11 (control) to 0.84

Cmol (P^+) kg^{-1} soil (site 2). In all the sites, at both the depths, the potassium contents ranged from 0.11 (0-30 cm) in control to 0.94 Cmol (P^+) kg^{-1} soil (15-30 cm) in site 4.

Sodium: The mean exchangeable sodium content of soils from all the sites showed increase over control. It ranged from 0.03 (control) to 2.68 Cmol (P^+) kg^{-1} soil (site 1). In all the sites, at both the depths, the sodium content varied from 0.02 (15-30 cm) in control to 3.36 Cmol (P^+) kg^{-1} soil (15-30 cm) site 2.

e) Per cent base saturation: The mean per cent base saturation of soils from all the sites showed decrease over control. It ranged from 67.58 (site 7) to 99.09 (site 8). In all the sites, at both the depths, the per cent base saturation values ranged from 62.8 (0-15 cm) in site 7 to 99.64 (15-30 cm) in control.

f) Calcium and magnesium ratio: The Ca/Mg ratio of soils from all the sites, except from site 7 showed decrease over control. It ranged from 1.05 (site 5) to 3.19 (control). In all the sites, at both the depths, the Ca/Mg ratio values ranged from 0.8 (15-30 cm) in site 5 to 4.0 (0-15 cm) in site 7.

Table 60 : Physico-chemical characteristics of soils treated with urban solid wastes

Location	Depth (cm)	pH			EC (d S m ⁻¹)			CEC (Cmol (P ⁺) kg ⁻¹ soil)			Base saturation (%)		
		0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
Site-1		7.9	7.2	7.6	0.372	0.281	0.326	31.51	28.42	29.96	87.20	71.85	79.52
Site-2		8.2	8.2	8.2	0.392	0.545	0.468	21.80	23.76	22.78	75.00	91.41	83.20
Site-3		8.5	8.2	8.4	0.648	0.482	0.565	17.50	18.40	17.95	82.34	83.30	82.82
Site-4		8.2	8.1	8.2	2.500	1.200	1.850	33.00	30.11	31.55	78.66	96.44	87.55
Site-5		8.4	8.5	8.5	0.865	1.440	1.152	18.90	16.81	17.86	72.88	87.92	80.40
Site-6		8.5	8.5	8.5	1.300	0.178	0.739	10.30	7.50	8.90	81.65	99.00	90.32
Site-7		8.1	8.2	8.2	0.090	0.080	0.085	16.40	14.48	15.44	62.80	72.37	67.58
Control site		6.0	6.1	6.1	0.040	0.050	0.045	6.85	11.12	8.98	98.54	99.64	99.09

Location	Depth (cm)	Exchangeable cations (Cmol (P ⁺) kg ⁻¹ soil)												Ca/Mg ratio		
		Calcium			Magnesium			Potassium			Sodium			0-15	15-30	Mean
		0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean			
Site-1		16.5	12.3	14.40	7.25	5.45	6.35	0.54	0.50	0.52	3.20	2.17	2.68	2.27	2.25	2.26
Site-2		10.5	12.2	11.35	3.25	5.30	4.27	0.82	0.86	0.84	1.79	3.36	2.57	3.23	2.30	2.76
Site-3		7.7	9.0	8.35	2.80	4.70	3.75	0.96	0.32	0.64	2.95	1.31	2.13	2.75	1.91	2.33
Site-4		17.5	18.7	18.10	5.75	6.80	6.27	0.65	0.94	0.33	2.06	2.60	2.33	3.04	2.75	2.89
Site-5		6.5	5.0	5.75	5.00	6.25	5.62	0.72	0.60	0.66	1.57	2.93	2.25	1.30	0.80	1.05
Site-6		3.7	3.3	3.50	2.50	2.20	2.35	0.38	0.38	0.38	1.83	1.55	1.69	1.48	1.50	1.49
Site-7		8.0	7.2	7.60	2.00	3.00	2.50	0.20	0.18	0.19	0.11	0.10	0.10	4.00	2.40	3.20
Control site		5.1	8.2	6.65	1.50	2.75	2.12	0.11	0.11	0.11	0.04	0.02	0.03	3.40	2.98	3.19

4.7.1.3 Chemical characteristics

a) Available nutrients

The data are presented in Table 61.

Nitrogen: The mean available nitrogen content of soil from all the sites showed increase over control. It ranged from 55.5 (control) to 122.5 ppm (site 4) or 124.35 to 274.35 kg N ha⁻¹, respectively. In all the sites, at both the depths, the available nitrogen contents ranged from 53.0 (15-30 cm) in control to 124.0 ppm (0-15 cm) in site 4 or 118.7 to 277.7 kg N ha⁻¹.

Phosphorus: The mean available phosphorus (as P₂O₅) content of soils from all the sites showed increase over control. It ranged from 8.35 (control) to 31.75 ppm (site 4) or 18.65 to 71.12 kg P₂O₅ ha⁻¹, respectively. In all the sites, at both the depths the phosphorus (as P₂O₅) contents ranged from 7.2 (15-30 cm) in control to 32.5 ppm (0-15 cm) in site 4 or 16.1 to 72.8 kg P₂O₅ ha⁻¹, respectively.

Potassium: The mean available potassium (as K₂O) content of soils from all the sites showed increase over control. It ranged from 52.5 (control) to 344.0 ppm (site 2) or 117.55 to 771.65 kg K₂O ha⁻¹, respectively. In all the sites, at both the depths, the potassium contents ranged from 51.0 (15-30 cm) in control site to 378.0 ppm (15-30 cm) in site 4 or 114.2 to 846.7 kg K₂O ha⁻¹, respectively.

Table 61 : Available nutrient content of soils treated with urban solid wastes

Location	Nitrogen			Phosphorus (as P ₂ O ₅)			Potassium (as K ₂ O)											
	Depth (cm)	ppm	N kg ha ⁻¹	ppm	kg P ₂ O ₅ ha ⁻¹	ppm	kg K ₂ O ha ⁻¹											
		0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean								
Site-1	105.0	94.0	99.5	235.2	210.5	222.85	31.5	29.4	30.45	70.5	65.8	68.15	222.0	205.0	213.5	497.2	459.2	478.20
Site-2	92.0	90.0	91.0	206.0	201.6	203.80	30.2	30.0	30.10	67.6	67.2	67.40	333.0	356.0	344.5	745.9	797.4	771.65
Site-3	82.0	80.0	81.0	183.6	179.2	181.40	32.0	28.1	30.05	71.6	62.9	67.25	400.0	133.0	266.5	896.0	297.9	596.95
Site-4	124.0	121.0	122.5	277.7	271.0	274.35	32.5	31.0	31.75	72.8	69.4	71.12	266.0	378.0	322.0	595.8	846.7	721.25
Site-5	107.0	118.0	112.5	239.6	264.3	251.95	29.0	26.0	27.50	65.0	58.2	61.58	289.0	244.0	266.5	647.4	546.5	596.95
Site-6	64.0	74.0	69.0	143.3	165.7	154.50	19.5	18.1	18.80	43.6	40.5	42.05	156.0	156.0	156.0	349.4	349.4	349.40
Site-7	110.0	96.0	103.0	246.4	215.0	230.70	28.2	20.5	24.35	63.1	45.9	54.50	94.0	82.0	88.0	210.5	183.6	197.05
Control site	58.0	53.0	55.5	130.0	118.7	124.35	9.5	7.2	8.35	21.2	16.1	18.65	54.0	51.0	52.5	120.9	114.2	117.55

b) **NH₄OAc-exchangeable sodium:** The mean sodium content of soils from all the sites showed increase over control. It ranged from 12.0 (control) to 740.0 ppm (site 1) or 26.88 to 1658.7 kg Na ha⁻¹, respectively. In all the sites, at both the depths the sodium contents ranged from 9.0 (15-30 cm) in control to 900.0 ppm (15-30 cm) in site 2 or 20.16 to 2016.0 kg Na ha⁻¹, respectively (Table 62).

c) **Organic carbon:** The mean organic carbon content of soils from all the sites showed increase over control. It ranged from 0.48 (control) to 1.85 per cent (site 4) (Fig. 15). In all the sites, at both the depths, the organic carbon content ranged from 0.42 (15-30 cm) in control to 1.9 per cent (0-15 cm) in site 4 (Table 62).

d) **Exchangeable sodium percentage (ESP):** The ESP of soils from all the sites showed increase over control (Fig. 16). It ranged from 0.38 (control) to 19.21 (site 6). In all the sites, at both the depths, the ESP values ranged from 0.18 (15-30 cm) in control to 20.66 (15-30 cm) in site 6. Among all the soil samples studied, only four samples exceeded the limit of ESP 15.0.

e) **Water soluble ions**

The data are presented in Table 63.

Potassium: The mean water soluble potassium content of soils from all the sites showed increase over

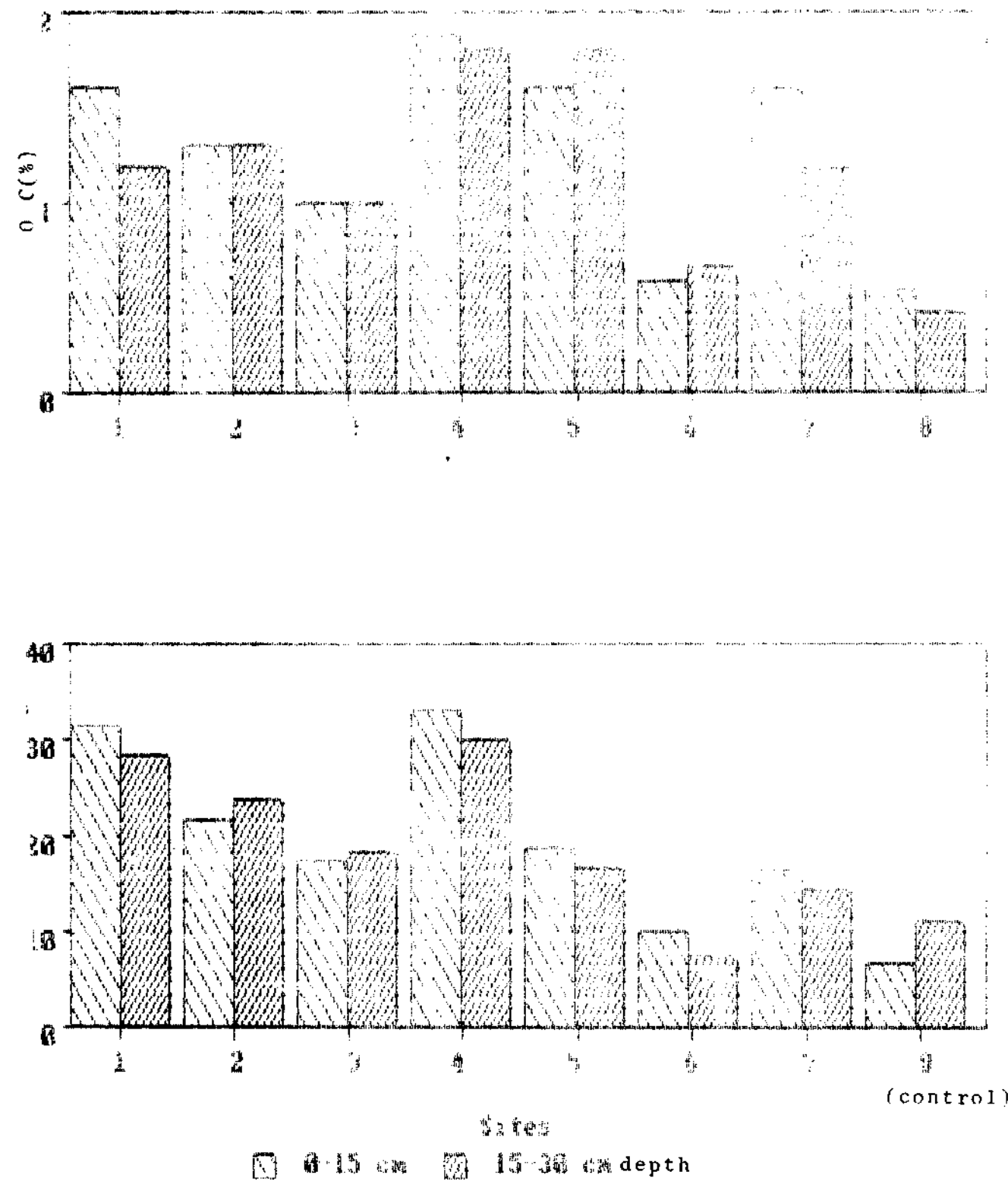


Fig. 15 Soil organic carbon and cation exchange capacity as affected by the application of USW in farmers fields

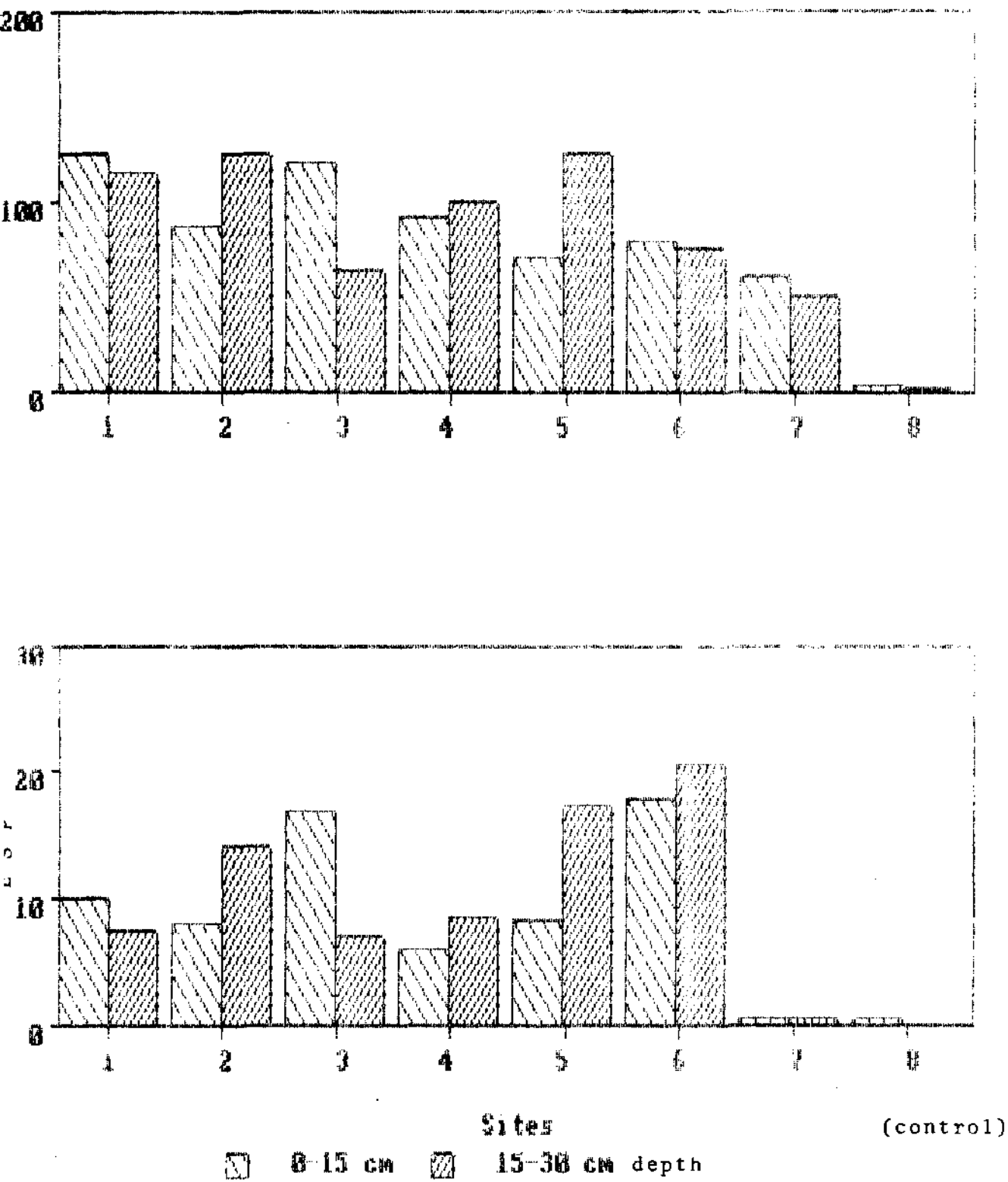


Fig.16 Water soluble sodium content and exchangeable sodium percentage in soil influenced by the application of USW in farmers field

Table 62 : Exchangeable sodium percentage, organic carbon and NH_4OAC -extractable sodium in soils treated with urban solid wastes

Location	E.S.P			Organic carbon (%)			NH_4OAC -extractable sodium ppm			Kg Na ha ⁻¹		
	Depth			Mean			Mean			Mean		
	(cm)	0-15	15-30	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
Site-1		10.15	7.63	8.89	1.6	1.2	1.4	866.0	615.0	740.5	1939.8	1377.6 1658.70
Site-2		8.21	14.14	11.17	1.3	1.3	1.3	500.0	900.0	700.0	1120.0	2016.0 1568.00
Site-3		16.85	7.11	11.98	1.0	1.0	1.0	800.0	367.0	583.5	1792.0	822.0 1307.00
Site-4		6.24	8.63	7.43	1.9	1.8	1.85	567.0	700.0	633.5	1270.0	1568.0 1419.00
Site-5		8.29	17.43	12.86	1.6	1.8	1.70	433.0	800.0	616.5	969.9	1792.0 1380.95
Site-6		17.76	20.66	19.21	0.6	0.67	0.63	500.0	433.0	466.5	1120.0	969.9 1044.95
Site-7		0.67	0.69	0.68	1.6	1.2	1.40	87.5	76.3	81.9	196.5	170.9 183.70
Control site		0.58	0.18	0.38	0.54	0.42	0.48	15.0	9.0	12.0	33.6	20.16 26.88

control. It ranged from 4.95 (site 6) to 15.85 ppm (site 2). In all the sites, at both the depths, the potassium contents varied from 4.8 (15-30 cm) in site 6 to 22.0 ppm (0-15 cm) in site 3.

Sodium: The mean sodium content of soils from all the sites showed increase over control (Fig. 16). It ranged from 3.65 (control) to 120.0ppm (site 1). In all the sites at both the depths, the sodium contents ranged from 3.1 (15-30 cm) in control to 126.0 ppm (15-30 cm) in site 5.

Sulphate: The mean sulphate content of soils from all the sites showed increase over control. It ranged from 2.0 (control) to 66.5 ppm (site 2). In all the sites at both the depths, the sulphate contents ranged from 1.0 (15-30 cm) in control to 90.0 ppm (0-15 cm) in site 3.

Chloride: The mean water soluble chloride content of soils from all the sites showed increase over control. It ranged from 1.25 (control) to 25.0 ppm (site 1). In all the sites, at both the depths, the chloride contents ranged from 0.50 (15-30 cm) in control to 30.0 ppm (15-30 cm) in site 5.

Table 63 : Water soluble ions in soils treated with urban solid wastes

Location	Potassium (K ⁺)			Sodium (Na ⁺)			Sulphate (SO ₄ ²⁻)			Chloride (Cl ⁻)			
	Depth (cm)	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
----- ppm -----													
Site-1		8.4	6.5	7.45	125.0	115.0	120.0	67.0	63.0	65.0	26.0	24.0	25.0
Site-2		12.7	19.0	15.85	87.5	125.0	106.25	51.0	82.0	66.5	19.0	29.0	24.0
Site-3		22.0	6.8	14.40	120.0	64.0	92.0	90.0	23.0	56.5	25.0	20.0	22.5
Site-4		9.6	10.5	10.05	92.0	100.0	96.0	23.0	51.0	37.0	20.0	29.0	24.5
Site-5		8.4	7.2	7.80	71.0	126.0	98.5	33.0	66.0	49.5	18.0	30.0	24.0
Site-6		5.1	4.8	4.95	79.0	76.0	77.5	35.0	31.0	33.0	20.0	18.0	19.0
Site-7		12.7	9.4	11.05	60.5	51.4	55.95	20.0	7.0	13.5	12.0	2.0	7.0
Control site		8.5	6.4	7.45	4.2	3.1	3.65	3.0	1.0	2.0	2.0	0.50	1.25

f) Total micronutrient and heavy metal contents

Data are presented in Table 64 and 65.

Iron: The mean total iron content of soils from all the sites showed decrease over control. It ranged from 2795.0 (site 6) to 14700.0 ppm (control). In all the sites, at both the depths, the total iron contents ranged from 2720.0 (15-30 cm) in site 6 to 14800.0 ppm (15-30 cm) in site 6 in control site.

Zinc: In contrast, the mean total Zn content of soils from all the sites showed increase over control. It ranged from 13.8 (control) to 176.7 ppm (site 4). In all the sites, at both the depths, the zinc contents ranged from 12.1 (15-30 cm) in control site 178.0 ppm (0-15 cm) in site 4.

Copper: Similarly, the mean total copper content of soils from all the sites, except two (sites 6 and 7) showed increase over control. It ranged from 4.2 (site 6) to 71.85 ppm (site 4). In all the sites, at both the depths, the copper contents ranged from 4.1 (0-15 cm) in site 6 to 73.3 ppm (15-30 cm) in site 4.

Manganese: The mean total manganese content of soils from four sites viz., sites 1, 2, 4 and 5 showed increase over control whereas in sites 3, 6 and 7, it decreased over control. In all the sites, at both the

Table 64 : Total micronutrients content in soils treated with urban solid wastes

Location	Depth cm	Iron (Fe)			Zinc (Zn)			Copper (Cu)			Manganese (Mn)		
		0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
----- ppm -----													
Site-1		7677.00	7452.00	7564.50	160.00	154.00	157.00	60.20	54.00	57.10	380.00	385.00	382.50
Site-2		7616.40	4677.50	6146.95	87.40	64.20	75.80	26.70	24.00	25.35	470.00	230.00	350.00
Site-3		3550.00	3140.00	3345.00	69.40	72.60	71.00	20.40	22.50	21.45	200.00	130.00	165.00
Site-4		7859.30	7677.00	7768.39	178.00	175.40	176.70	70.40	73.30	71.85	360.00	370.00	365.00
Site-5		5556.30	4980.60	5268.45	167.90	151.90	159.90	64.30	62.20	63.25	310.00	360.00	335.00
Site-6		2870.00	2720.00	2795.00	40.90	36.90	38.90	4.10	4.30	4.20	90.00	91.00	90.50
Site-7		3430.00	3250.00	3340.00	35.10	31.20	33.15	6.20	5.40	5.80	170.00	164.00	167.00
Control site		14600.00	14800.00	14700.00	15.50	12.10	13.80	8.50	6.50	7.50	180.00	210.00	195.00

depths, the manganese contents ranged from 90.0 (0-15 cm) in site 6 to 470.0 ppm (0-15 cm) in site 2.

Lead: The mean total lead content of soils from all the sites showed increase over control. It ranged from 5.15 (control) to 170.10 ppm (site 1). In all the sites, at both the depths, the total lead contents ranged from 4.3 (15-30 cm) in control site to 172.0 ppm (0-15 cm) in site 1.

Nickel: The mean total nickel content of soils from all the sites, except from site 7 showed increase over control. It ranged from 0.95 (site 7) to 10.25 ppm (site 1). In all the sites, at both the depths, the nickel contents ranged from 0.9 (15-30 cm) in site 7 to 12.6 ppm (15-30 cm) in site 4.

Cobalt: The mean total cobalt content of soils from sites 1, 2, 4 and 7 showed increase, whereas in case of sites 3, 5 and 6, the contents decreased over control. It ranged from 2.0 (site 6) to 7.0 ppm (site 4). In all the sites, at both the depths, the cobalt contents ranged from 1.0 (15-30 cm) in site 6 to 9.0 ppm (15-30 cm) in site 4.

Cadmium: The mean cadmium content of soils from all the sites, except from site 7 showed increase over control. It ranged from 0.40 (site 7) to 0.85 ppm (site 2). In all the sites, at both the depths, the

cadmium contents ranged from 0.3 (15-30 cm) in site 7 to 0.9 ppm (15-30 cm) in site 2.

Chromium: The mean chromium content of soils from all the sites, except from site 7 showed increase over control. It ranged from 5.95 (site 7) to 47.85 ppm (site 5). In all the sites, at both the depths, the chromium contents ranged from 5.4 (15-30 cm) in site 7 to 50.0 ppm (0-15 cm) in site 4.

g) DTPA-extractable micronutrients and heavy metals

Data are presented in Table 66 and 67.

Iron: The iron content of soils from all the sites, except from site 7 showed increase over control. It ranged from 4.0 (site 7) to 52.50 ppm (site 1). In all the sites, at both the depths, the iron contents ranged from 3.5 (15-30 cm) in site 7 to 57.0 ppm (0-15 cm) in site 1.

Zinc: The mean zinc content of soils from all the sites showed increase over control. It ranged from 0.81 (control) to 14.75 ppm (site 1). In all the sites, at both the depths, the zinc contents ranged from 0.62 (15-30 cm) in control site to 15.2 ppm (0-15 cm) in site 1 (Fig. 17).

Copper: The mean copper content of soils from all the sites showed increase over control. It varied from 0.81 (control) to 27.5 ppm (site 1). In all the sites, at both the depths, the copper contents ranged from 0.72 (15-30 cm) in control site to 28.6 ppm (0-15 cm) in site 1 (Fig. 17).

Manganese: The manganese contents of four sites 1, 2, 4 and 6 showed increase while they decreased in sites 3, 5 and 7 over control. The Mn content ranged from 3.2 (site 7) to 19.95 (site 1). In all the sites, at both the depths, the manganese contents ranged from 2.8 (15-30 cm) in site 7 to 25.8 ppm (0-15 cm) in site 4.

Lead: The mean lead content of soils from all the sites showed increase over control. It ranged from 0.03 (control) to 25.05 (site 1). In all the sites, at both the depths, the lead contents ranged from 0.02 (0-15 cm) in control site to 27.2 ppm (15-30 cm) in site 4 (Fig. 18).

Nickel: The mean nickel content of soils from all the sites showed increase over control. It ranged from 0.035 (control) to 0.90 ppm (site 1). In all the sites, at both the depths, the nickel contents ranged from 0.02 (15-30 cm) in control site to 1.0 ppm (0-15 cm) in site 1 (Fig. 18).

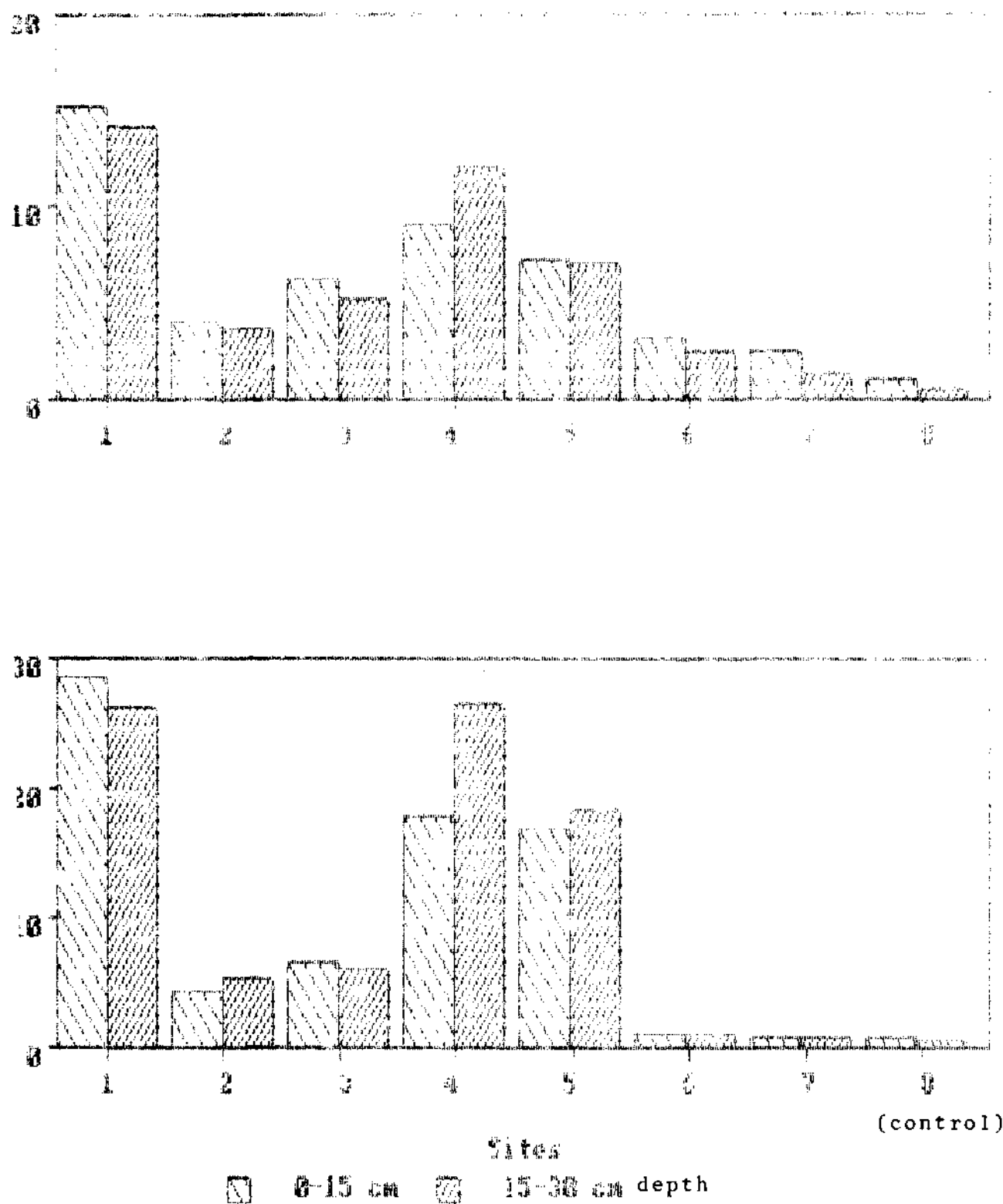


Fig. 17 The DTPA-extractable zinc and copper content of soils affected by application of USW in farmers fields

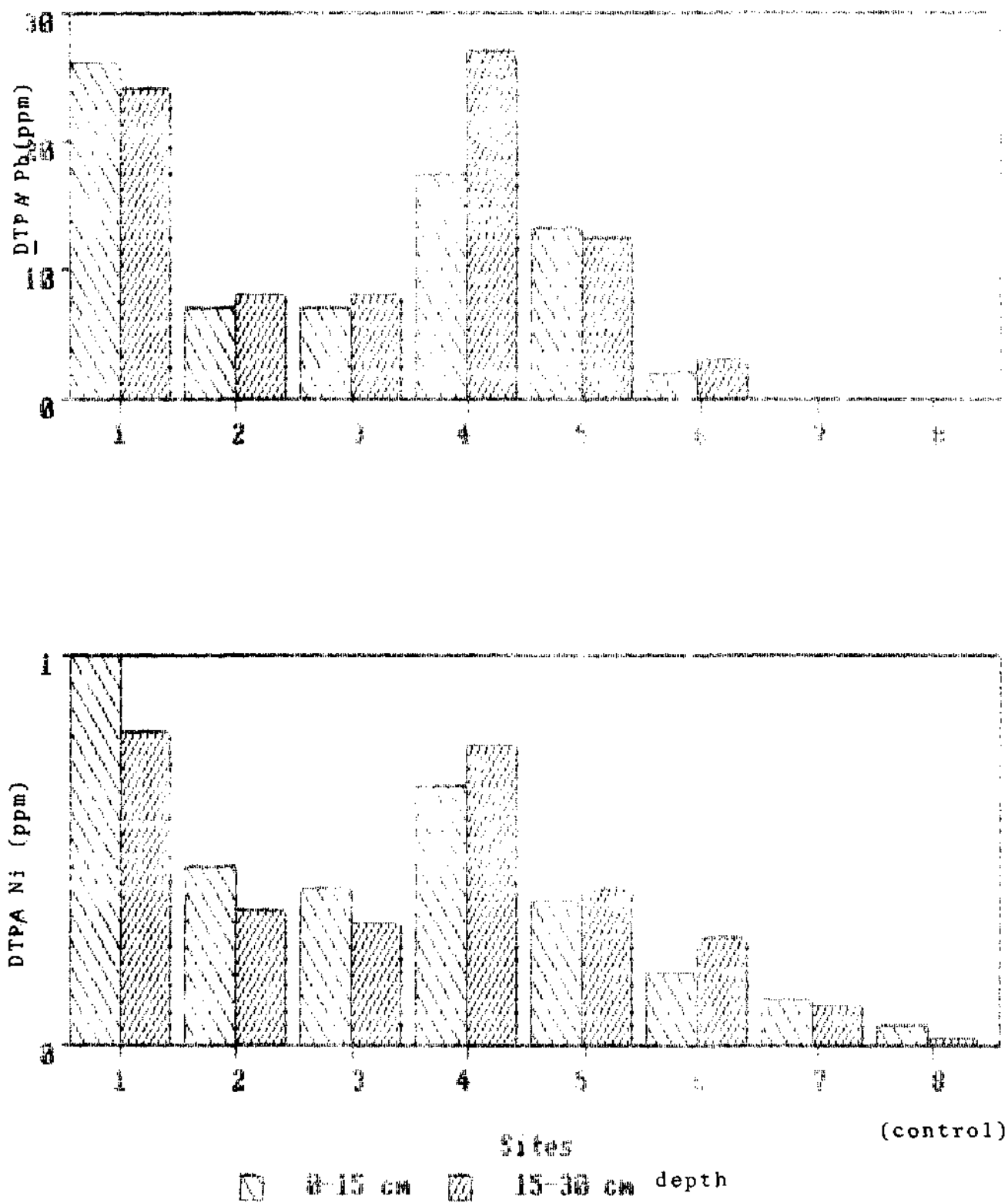


Fig. 18 The DTPA -extractable lead and nickel content of soils as affected by application of USW in farmers fields

Table 66 : DTPA-extractable micronutrients in soils treated with urban solid wastes

Location	Iron (Fe)			Zinc (Zn)			Copper (Cu)			Manganese (Mn)			
	Depth (cm)	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
-----ppm-----													
Site-1		57.00	48.00	52.50	15.20	14.20	14.75	28.60	26.40	27.50	19.80	20.10	19.95
Site-2		6.60	12.40	9.50	4.00	3.70	3.85	4.30	5.30	4.80	17.20	13.00	15.10
Site-3		16.00	12.00	14.00	6.20	5.20	5.70	6.60	6.20	6.40	12.20	4.00	8.10
Site-4		13.00	24.40	18.70	9.10	12.00	10.55	17.80	26.70	22.25	25.80	12.40	19.10
Site-5		7.20	11.60	9.40	7.30	7.00	7.15	16.80	18.30	17.55	11.00	8.80	9.90
Site-6		9.40	11.20	10.30	3.30	2.60	2.95	1.10	1.00	1.05	22.40	10.80	16.60
Site-7		4.50	3.50	4.00	2.50	1.40	1.95	0.92	0.81	0.86	3.60	2.80	3.20
Control site		6.50	4.80	5.65	1.00	0.62	0.81	0.90	0.72	0.81	9.00	11.00	10.00

Table 67 : DIPA-extractable heavy metals in soils treated with urban solid wastes

Location	Lead (Pb)		Nickel (Ni)		Cobalt (Co)		Cadmium (Cd)		Chromium (Cr)	
	Depth (cm)	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
----- ppm -----										
Site-1		26.00	24.10	25.05	1.00	0.80	0.90	0.34	0.30	0.32
								0.23	0.20	0.21
								0.27	0.22	0.24
Site-2		7.20	8.00	7.60	0.46	0.35	0.40	0.36	0.30	0.33
								0.15	0.16	0.15
								0.34	0.54	0.44
Site-3		7.00	8.00	7.50	0.40	0.31	0.35	0.28	0.22	0.25
								0.15	0.15	0.15
								0.29	0.15	0.22
Site-4		17.70	27.20	22.45	0.67	0.77	0.72	0.34	0.28	0.31
								0.17	0.26	0.21
								0.27	0.24	0.25
Site-5		13.40	12.70	13.05	0.37	0.40	0.38	0.22	0.22	0.22
								0.18	0.17	0.17
								0.50	0.36	0.43
Site-6		2.10	3.00	2.55	0.19	0.28	0.23	0.28	0.26	0.27
								0.10	0.12	0.11
								0.25	0.35	0.30
Site-7		0.10	0.10	0.10	0.12	0.10	0.11	1.00	0.80	0.90
								ND	ND	ND
								0.50	0.30	0.40
Control site		0.04	0.02	0.03	0.05	0.02	0.03	0.04	0.02	0.03
								ND	ND	ND
								ND	ND	ND

ND - Not detected.

Cobalt: The mean cobalt content of soils from all the sites showed increase over control. It ranged from 0.03 (control) to 0.9 ppm (site 7). In all the sites, at both the depths, the cobalt contents ranged from 0.02 (15-30 cm) in control site to 1.0 ppm (0-15 cm) in site 7.

Cadmium: The mean cadmium content of soils from all the sites, except from site 7 showed increase over control. It ranged from not detectable (site 7 and control) to 0.215 (site 1 and 4) ppm. In all the sites, at both the depths, the cadmium contents ranged from not detectable (site 7 and control) to 0.26 ppm (15-30 cm) in site 4.

Chromium: The chromium content of soils from all the sites showed increase over control. It ranged from not detectable (control) to 0.44 (site 2) ppm. In all the sites, at both the depths, the chromium contents ranged from not detectable (control) to 0.54 ppm (15-30 cm) in site 2.

h) Relative availability of micro-nutrients and heavy metals

Data are presented in Table 68, 69 and 70.

Among all the micronutrients and heavy metals in solid waste treated soils, Cu, Cd, Ni, Pb and Zn were

Table 68 : Relative availability (%) of micronutrients in soils treated with urban solid wastes

Location	Depth (cm)	Iron (Fe)			Zinc (Zn)			Copper (Cu)			Manganese (Mn)		
		0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
Site-1		0.74	0.64	0.69	9.50	9.28	9.39	47.50	48.88	48.19	5.21	5.22	5.21
Site-2		0.08	0.26	0.17	4.57	5.76	5.16	16.10	22.08	19.09	3.65	5.65	4.65
Site-3		0.45	0.38	0.42	8.93	7.16	8.04	32.35	27.55	29.95	6.10	3.07	4.58
Site-4		0.16	0.31	0.24	5.11	6.84	5.97	25.28	36.42	30.85	7.16	3.35	5.25
Site-5		0.12	0.23	0.18	4.34	4.60	4.47	26.12	29.42	27.77	3.54	2.44	2.99
Site-6		0.32	0.41	0.37	8.06	7.04	7.55	26.82	23.25	25.03	24.88	11.86	18.37
Site-7		0.13	0.10	0.12	7.12	4.48	5.80	14.83	15.00	14.91	2.11	1.70	1.90
Control site		0.04	0.03	0.04	6.45	5.12	5.78	11.76	9.53	10.64	5.00	5.23	5.11

$$\text{Relative availability (\%)} = \frac{\text{DTPA - metal}}{\text{Total metal}} \times 100$$

Table 69: Relative availability (%) of heavy metals in soils treated with urban solid wastes

Location	Depth (cm)	Lead (Pb)			Nickel (Ni)			Cobalt (Co)			Cadmium (Cd)			Chromium (Cr)		
		0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean	0-15	15-30	Mean
Site-1		15.11	14.32	14.71	9.00	8.42	8.71	4.85	4.61	4.73	28.75	28.57	28.66	0.74	0.69	0.72
Site-2		7.34	12.17	9.75	7.18	20.58	13.88	4.50	15.00	9.75	18.75	17.77	18.26	2.51	2.25	2.38
Site-3		10.90	10.13	10.51	4.59	9.39	6.99	9.33	7.33	8.33	18.75	18.75	18.75	0.78	0.42	0.60
Site-4		11.83	21.58	16.70	67.00	6.11	36.55	6.80	3.11	4.95	21.25	32.50	26.87	0.54	1.17	0.85
Site-5		10.76	12.21	11.48	4.40	4.49	4.44	11.00	4.41	7.70	25.71	18.88	22.29	1.08	0.72	0.90
Site-6		2.93	3.53	3.23	17.27	4.82	11.04	9.33	26.00	17.66	12.50	17.14	14.82	0.52	1.60	1.06
Site-7		0.83	0.94	0.88	12.00	11.11	11.55	14.28	12.30	13.29	ND	ND	ND	7.69	5.50	6.59
Control site		0.66	0.46	0.56	2.00	1.00	1.50	0.72	0.45	0.58	ND	ND	ND	ND	ND	ND

Tabl 70: Mean relative availability (%) of micronutrients and heavy metals in soils treated with urban solid wastes

=====	
Site 1	Cu (48.19) > Cd (28.66) > Pb (14.71) > Zn (9.39) > Ni (8.71) > Mn (5.21) > Co (4.73) > Cr (0.72) > Fe (0.69)
Site 2	Cu (19.09) > Cd (18.26) > Ni (13.88) > Pb (9.75) > Co (9.75) > Zn (5.16) > Mn (4.65) > Cr (2.38) > Fe (0.17)
Site 3	Cu (29.95) > Cd (18.75) > Pb (10.51) > Co (8.33) > Zn (8.04) > Ni (6.99) > Mn (4.58) > Cr (0.60) > Fe (0.42)
Site 4	Ni (36.55) > Cu (30.85) > Cd (26.87) > Pb (16.70) > Zn (5.97) > Mn (5.25) > Co (4.95) > Cr (0.85) > Fe (0.24)
Site 5	Cu (27.77) > Cd (22.29) > Pb (11.48) > Co (7.70) > Zn (4.47) > Ni (4.44) > Mn (2.99) > Cr (0.90) > Fe (0.18)
Site 6	Cu (25.03) > Mn (18.37) > Co (17.66) > Cd (14.82) > Ni (11.04) > Zn (7.55) > Pb (3.23) > Cr (1.06) > Fe (0.37)
Site 7	Cu (14.91) > Co (13.29) > Ni (11.55) > Cr (6.59) > Zn (5.80) > Mn (1.90) > Pb (0.88) > Fe (0.12) > Cd (ND)
Control	Cu (10.64) > Zn (5.78) > Mn (5.11) > Ni (1.50) > Co (0.58) > Pb (0.56) > Fe (0.04) > Cd (ND) > Cr (ND)
Site	
=====	
Values in parenthesis indicates mean relative availability (%) of elements.	
ND - Not detected	

available relatively more than others. The least available are Fe, Cr, Co and Mn.

While in control site, the elements Cu, Zn, Mn and Ni are relatively more available than others, the least available are Co, Pb and Fe. The elements Cd and Cr are not in available form.

The relative availability of micronutrients in waste treated soils varied as follows:

Iron - 0.04 (control) to 0.69 (site 1), zinc - 4.47 (site 5) to 9.39 (site 1), copper - 10.64 (control) to 48.19 (site 1) and manganese - 1.9 (site 7) to 18.37 (site 6) per cent.

The relative availability of heavy metals in waste treated soils varied as follows:

Lead 0.56 (control) to 16.7 (site 4), nickel 1.5 (control) to 36.55 (site 4), cobalt 0.58 (control) to 17.66 (site 6), cadmium traces (site 7 and control) to 28.66 (site 1) and chromium traces (control) to 6.59 (site 7) per cent.

4.7.2 Contents of micronutrients and heavy metals in plants collected from raw USW treated soils around Hyderabad City

Data are presented in Table 71.

4.7.2.1 Micronutrients

a) **Iron:** The content of iron in root ranged from 258.0 (bottleguord) to 4685.0 ppm (brinjal) whereas in shoot, they ranged from 287.0 (jowar-Golkonda) to 3828.0 ppm (bottleguord). In fruit and seed, the values ranged from 390.0 (bhendi) to 875.0 ppm (paddy).

The contents of iron were more in roots than in shoots in Hibiscus sp., chillies, jowar, tomato and brinjal but in some plants, they were more in shoots than in roots (radish, bottleguord, parthenium and beet-root).

b) **Zinc:** The contents of zinc in roots ranged from 13.0 (bottleguord) to 232.0 ppm (brinjal) whereas in shoot, they ranged from 46 (chilli-sampled from Golkonda) to 111.0 ppm (beetroot). In fruit and seed, the values ranged from 40.0 (chilli-collected from Upperpalli) to 70.0 ppm (bhendi).

The contents of zinc were more in roots than in shoots (radish, jowar, chilli-Golkonda, tomato and brinjal) whereas in some plants, the values were more in shoots than in roots (bottleguord, parthenium, bhendi, chillies-Upperpalli and beetroot).

c) **Copper :** The contents of copper in roots ranged from 4.3 (bottleguord) to 51.0 ppm (brinjal) whereas in

shoots, they ranged from 6.9 (chilli-collected from Golkonda) to 109.8 ppm (parthenium). In fruit and seed, the values ranged from 7.5 (jowar-obtained from Golkonda) to 11.8 ppm (chilles-Upperpalli).

The contents of copper were more in roots than in shoots bhendi, Hibiscus, chillies, jowar and tomato) whereas in some plants, they were more in shoots than in roots (radish, bottleguord, beetroot, parthenium and brinjal).

d) **Manganese:** The contents of manganese in roots ranged from 3.0 (bottleguord) to 171.0 ppm (tomato) and in shoots they ranged from 29.0 (jowar-collected from Golkonda) to 704.0 ppm (paddy). In fruit and seed, the values varied from 1.0 (chillies-sampled from Upperpalli) to 64.0 ppm (paddy).

The contents of manganese were more in roots than in shoots (chilli, jowar, tomato) whereas in some plants, they were more in shoots than in roots (radish, bottleguord, parthenium, bhendi, Hibiscus and brinjal).

4.7.2.2 Heavy metals

a) **Lead:** The contents of lead in roots ranged from 10.5 (parthenium) to 160.0 ppm (bottleguord) whereas in shoots, they ranged from 3.4 (beetroot and paddy) to 64.0 ppm (chillies-obtained from Upperpalli). In fruit

and seed, the values varied from 0.4 (paddy) to 0.7 ppm (chillies-obtained from Upperpalli).

The contents of lead were more in roots than in shoots (bottleguord, bhendi, Hibiscus, jowar, chillie-collected from Golkonda, tomato and brinjal) whereas in some plants, the values were more in shoots than in roots (radish parthenium, chilli-Upperpalli and beetroot).

b) Nickel: The contents of nickel in roots ranged from 1.8 (parthenium) to 15.0 ppm (bottleguord) whereas in shoots, they ranged from 0.2 (jowar-collected from Upperpalli) to 11.5 ppm (bottleguord). In fruits and seed, the values ranged from 0.1 (chilli obtained from Upperpalli) to 0.7 ppm (bhendi).

The contents of nickel were more in roots than in shoots (bottleguord, bhendi, Hibiscus, chillies, jowar, tomato and brinjal) while in some plants the values were more in shoots than in roots (parthenium).

c) Cobalt: The contents of cobalt in roots ranged from 2.0 (jowar-collected from Golkonda) to 6.2 ppm (jowar-Upperpalli). In shoots they ranged from 0.30 (Hibiscus) to 0.75 ppm (bottleguord). In fruit and seed, the values ranged from 0.03 (paddy) to 0.06 ppm (chilli and bhendi).

The contents of cobalt were more in roots than in shoots in all the plants sampled.

d) Chromium:

The contents of chromium in roots ranged from 0.45 (parthenium) to 7.7 ppm (bottleguord). In shoots, they ranged from 0.2 (tomato) to 2.0 ppm (parthenium). In fruits and seeds, the values ranged from traces (paddy and jowar) to 0.02 ppm (chillies and bhendi).

The contents of chromium were more in roots than in shoots (bottleguord, bhendi, Hibiscus, chillies, jowar, tomato and brinjal) whereas in some plants, the values were more in shoots than in roots (parthenium).

e) Cadmium: The contents of cadmium in roots ranged from only traces (jowar sampled from Golkonda) to 2.5 ppm (parthenium). In shoots, they ranged from not detectable (Hibiscus and jowar) to 2.0 ppm (parthenium). In fruits and seeds, the values ranged from traces (bhendi, paddy and jowar) to 0.1 ppm (chilli).

The contents of cadmium were more in roots than in shoots of all the plants studied.

The direct application of urban solid wastes as manure for cultivating crops is practiced widely in and around Hyderabad. This practice definitely has brought about drastic modifications in soil properties and has also affected the uptake of plant nutrients and heavy metals. Though the overall effect of the direct application of urban solid wastes succeeds in providing a

Table 71: Concentration of metals in plant tissue grown on urban solid waste treated soils around Hyderabad city

Site No. (Location)	Plant type	Plant part assayed	Dry weights (g)	Fe	Zn	Cu	Mn	Pb	Ni	Co	Cr	Cd
ppm												
1	Paddy	Straw	At harvest	635	55	16.25	704	3.40	0.30	0.60	0.05	0.50
		Seed	,,	875	46	9.90	64	0.40	0.30	0.03	ND	ND
2	Chillies	Root	1.5	2420	73	42.00	58	40.00	11.90	6.10	3.60	0.50
		Shoot	23.0	835	88	37.50	39	64.00	3.00	0.54	0.40	0.20
		Fruit	0.50	580	40	11.80	1.0	0.70	0.10	0.06	0.02	0.10
	Jowar	Root	1.50	2374	205	18.10	108	25.00	2.30	6.20	6.80	0.50
		Shoot	8.30	840	74	8.50	83	8.30	0.20	0.48	0.90	ND
	Bottle-gourd	Root	0.80	258	13	4.30	3.0	160.00	15.00	4.00	7.70	2.00
3		Shoot	16.00	3828	68	20.90	108	26.10	11.50	0.75	0.30	0.80
	Parthenium	Root	2.50	365	29	10.30	19	10.50	1.80	5.50	0.45	2.50
		Shoot	25.00	665	85	109.80	73	60.0	4.60	0.55	2.00	2.00
	Bhendi	Root	1.50	1335	49	14.50	58	31.20	9.40	5.40	3.50	2.00
		Shoot	36.00	1720	65	14.10	83	7.90	7.00	0.60	0.90	0.50
		Fruit	10.00	390	70	11.20	49	0.10	0.70	0.06	0.02	ND
	Gongura (Hibiscus sp.)	Root	0.50	2060	72	13.60	68	48.00	8.60	4.50	6.10	1.50
		Shoot	10.00	830	70	10.70	201	1.20	0.40	0.30	0.10	ND
	Beetroot	Root	4.30	675	85	12.40	44	2.20	0.25	0.50	0.30	0.50
		Shoot	3.00	1280	111	21.00	128	3.40	2.50	0.30	0.60	1.00
	Radish	Tuber	19.00	770	98	9.10	49	1.20	0.95	0.04	0.60	0.15
		Shoot	20.00	790	73	9.70	103	18.10	4.60	0.45	0.50	1.00
6	Chillies	Root	0.60	764	51	13.10	49	15.10	7.80	4.50	1.20	2.00
		Shoot	3.40	425	46	6.90	38	7.50	3.00	0.55	1.00	0.50
	Tomato	Root	0.17	3029	167	27.00	171	47.00	11.50	3.00	1.10	1.00
		Shoot	7.83	775	48	12.00	98	3.70	2.90	0.10	0.20	0.50
	Brinjal	Root	0.145	4685	232	51.00	98	43.00	13.00	3.50	2.30	2.00
		Shoot	6.85	1835	96	77.00	103	14.00	4.50	0.15	0.80	1.00
7	Jowar	Root	12.00	1954	48	30.00	65	12.10	3.00	2.00	4.80	ND
		Shoot	42.00	287	47	20.10	29	7.75	0.75	1.25	0.35	ND
		Seed	3.00	860	66	7.50	29	0.40	0.40	0.05	ND	ND

ND - Not detected

better crop stand, the cause for concern appears to be land degradation due to salt accumulation, build up of micronutrients and heavy metals concentration to toxic levels and the uptake of heavy metals by plants which will ultimately reach the food chain.

DISCUSSION

CHAPTER V

DISCUSSION

The results of the research work carried out on soil and water resources characteristics, in relation to land disposal of urban solid wastes described in the preceeding chapter, are discussed in the following paragraphs :

5.1 PROPERTIES OF URBAN SOLID WASTES

5.1.1 Physical composition

Urban refuse is comprised mainly of domestic and industrial wastes generated in urban areas. Sewage sludge does not form a component of the urban solid wastes generated in metropolitan areas because sewage is piped and disposed off separately in most cities in India as well as in other countries. The physical composition of urban solid wastes generated in Hyderabad city, which is the area of study of these investigations is presented in Table 15.

The unsorted, unshredded fresh urban solid waste from Autonagar and Golkonda landfill sites contained 12.5 and 6.2 per cent gravel, 1.0 and 0.5 per cent glass, 7.0 and 2.1 per cent rags, 2.0 and 2.0 per cent paper, 1.0 and 1.3 per cent metals, 2.1 and 1.6 per cent leather and rubber, 1.0 and 1.4 per cent plastics, 35.0

and 20.5 per cent earth and ash, 20.0 and 37.1 per cent compostable matter, 18.40 and 27.3 per cent miscellaneous matter and 410.0 and 365.0 kg m⁻³ density respectively. Olaniya and Saxena (1977) reported the physical characteristics of refuse from different dumping grounds of Jaipur (India) as 3.60 - 23.60 per cent stone, 0.20 - 2.80 per cent coal, 0.06 - 1.90 per cent glass, 0.90 - 22.20 per cent rages, 0.60 - 4.56 per cent papers, 0.01 - 1.70 per cent metals, 0.16 - 0.30 per cent hairs, 0.30 - 3.30 per cent leather and rubber, 0.05 - 3.00 per cent plastics, 0.07 - 0.50 per cent bone, 18.30 - 46.90 per cent compostable matter and 34.00 - 64.50 per cent earth. Patel and Tiwari (1990) reported the characteristics of refuse from industrial areas of Rourkela. The mean values of different components were reported as 41.50 per cent construction material, 47.70 per cent dust and cinder, 3.40 per cent scrap metal, 1.10 per cent paper and card board, 0.80 per cent glass, 1.20 per cent broken china, 1.00 per cent mica, 1.00 per cent polythene and 2.30 per cent miscellaneous.

The non-compostable matter is more in Autonagar solid wastes than Golkonda wastes. The compostable matter is more in Golkonda than in Autonagar fresh wastes. This is mainly due to the fact that the major portions of wastes generated at Golkonda are from market yards, public eating places like hotels, tea shops and residential locations.

The physical characteristics of stabilized wastes from Amberpet and Golkonda are presented in Table 15.

The results revealed that Amberpet stabilized wastes contained more non-compostable matter as compared to Golkonda wastes, because the Golkonda landfill site receives most of the wastes from market yards, vegetable markets, hotels and residential areas.

King et al. (1974) analysed unsorted, shredded municipal refuse from St. Catherines, Ontario, Canada which contained 71.20 per cent paper, 5.20 per cent plastic, 8.30 per cent metal, 5.00 per cent glass and dust, 1.30 per cent miscellaneous and 48.6 per cent moisture. This clearly shows that the wastes generated in urban areas in western countries contained more paper, plastic, metal and glass than the wastes generated at Hyderabad or other Indian cities.

Radia Khatib et al. (1990) studied the municipal waste from Karachi (Pakistan) and reported that it contained 89.50 per cent (dry basis) total recyclable material with plastics 9.85 per cent, paper 10.10 per cent, glass 1.24 per cent, bones 1.85 per cent metal 0.74 per cent, leather and rubber 0.20 per cent organic vegetable matter, 54.50 per cent as the major components.

It is very difficult to compare the solid waste composition of a country with other cities on account of

general scarcity of accurate, reliable and complete measurement on a comparable basis, difference in collection and disposal practice, geographical situation, capacity of land, seasonal variation in waste production and characteristics including standard of living and economic conditions (Bhide, 1984).

However, an attempt has been made to summarise the data for different cities in India as well as western countries for purpose of comparison with the urban solid wastes generated in Hyderabad. This is presented in Table 72.

Hyderabad is one of the rapidly growing metropolis in India and there is a lot of construction activity. Also as the surroundings of the city are barren without a green cover, the winds blowing into the city transport a lot of dust. The presence of higher quantities of earth (soil) and ash in urban solid waste of many Indian cities is due to a collection system wherein the street sweepings are mixed with refuse. Studies conducted by Bhide (1984) showed that the earth and ash content in wastes exhibited a decrease with an increase in population density in Indian cities. The relative contribution of paper, metals, plastics and glass in Hyderabad urban solid wastes is low as compared to refuse from western countries, which is because of salvaging of these components for recycling from the

Table 72 : Comparative physical composition of fresh urban solid wastes generated in Hyderabad city, other representative Indian cities and developed countries

S. No.	Characteristics	Hyderabad		Range of variability of solid waste generated in Indian cities		Developed countries
		Autonagar	Golkonda	Nagpur (Bhide and Muley, 1973)	Indian urban refuse (Bhide, 1984)	(Mutatkar, 1985)

--dry weight basis--		----- wet weight basis -----				
----- (%) -----						
1.	Gravel	12.50	6.20	--	--	--
2.	Glass	1.00	0.50	0.19	0.3 - 0.8	3-10
3.	Rags and Textile	7.00	2.10	0.64	--	--
4.	Paper	2.00	2.00	1.99	3-7	20-50
5.	Metals	1.00	1.30	--	0.4 - 0.9	4-14
6.	Leather	2.10	1.60	--	--	--
7.	Plastic and Polythene	1.00	1.40	0.27	0.5 - 0.9	1-3
8.	Earth and Ash	35.00	20.50	--	30 - 50	3-10
9.	Compostable matter	20.00	37.10	--	30 - 50	10-20
10.	Miscellaneous	18.40	27.30	--	--	--
11.	Fruit and Vegetable Matter	--	--	3.79	--	--
12.	Leaves	--	--	1.45	--	--
13.	Hay and Straw	--	--	12.90	--	--

waste bins provided in the streets or at the landfill site. This is very well depicted in the Plate 3. It is estimated that few thousand persons are engaged in salvaging of waste components for recycling to make a living out of the avocation at Hyderabad. In this respect, the situation with regard to waste disposal problems is better in Indian cities as compared to industrialized and advanced countries where such salvaging and recycling of waste components is non-existent, thus, creating serious environmental problems in respect of disposal of waste components like metals, paper, plastics, glass and rubber.

The weight-volume relationship of refuse in Hyderabad city varied from 410.0 kg m^{-3} for Autongar fresh solid wastes, 365.0 kg m^{-3} for Golkonda fresh wastes, 480.0 kg m^{-3} for stabilized Amberpet wastes and 265.0 kg m^{-3} for stabilized Golkonda wastes. The density of Hyderabad city refuse is higher when compared to other western countries, because of the higher content of earth and ash in the wastes. In many other Indian cities, the density of urban refuse reported ranged from 330.0 to 560.0 kg m^{-3} (Bhide, 1984).

Detailed analysis of the physical composition of wastes helps in the selection of a suitable disposal system (Bhide, 1984).

5.1.2 Physico-chemical and chemical properties

Data presented in Tables 17 and 18 provide some of the physico-chemical and chemical properties of fresh and stabilized USW only. A detailed study of results gives many interesting insights regarding the chemical nature of solid wastes from Hyderabad city.

5.1.2.1 Physico-chemical properties: The urban solid waste samples were slightly alkaline to strongly alkaline in reaction and the pH ranged from 7.70 (ASW 3) to 9.60 (GSF). Bhide and Muley (1973) reported pH of Nagpur city refuse as 7.90. Mutatkar (1985) reported that pH of the Indian city refuse ranged from 7.68 to 8.40. Olaniya and Saxena (1977) reported a pH range of 7.20 to 8.20 for Jaipur city refuse. In Rourkela industrial city, the pH of the urban solid waste ranged from 6.80 to 7.40 (Patel and Tiwari, 1990). Bhide and Sundaresan (1983) reported that in Indian city refuse the average pH was 7.68. Gupta et al. (1984) studied the Calcutta city waste and reported that the refuses were neutral to alkaline in reaction. Gupta et al. (1986) studied the nature of waste compost obtained from urban wastes of Calcutta and reported that the pH is neutral to slightly alkaline in reaction, ranging from 7.50 to 8.10. For Bombay city wastes, the pH reported was 7.70 (Ramachandran and D'Souza, 1990). The pH of wastes mainly depends on the source and characters which will affect physical

composition of wastes. In general, urban solid wastes are usually alkaline in reaction due to presence of CO_3 , HCO_3 , Na, K and other alkaline materials in varying concentrations.

The electrical conductivity of wastes varied greatly. It ranged from 130 (AFW) to 530 (GSW 2) $\mu\text{S m}^{-1}$ in 1 : 50 waste : water extracts. Significant differences in EC were observed from one landfill site (Amberpet) to another (Golkonda). The EC of stabilized solid wastes (Amberpet) in 1 : 2 waste water extracts, ranged from 0.97 (sample 4) to 4.48 (sample 3) d S m^{-1} with a mean of 2.85. Gupta et al. (1986) reported that the EC for Calcutta city waste composts ranged from 1.04 to 2.05 d S m^{-1} in 1 : 2 waste : water extracts.

The two hazards most often encountered in wastes are high total salts and sodium content levels. Excess total salts in urban solid wastes adversely affect germination and growth of seeds of crop plants when used as manure directly. High Na levels and K, to a lesser degree, cause dispersion of soil particles, poor soil structure and reduced infiltration rates. Therefore, the nature of salts as well as application rates should be considered while using wastes on agricultural land.

The organic carbon contents of wastes ranged from 3.40 (AFW) to 6.30 per cent (GSW). Organic carbon

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6.2.9

contents of Golkonda wastes was more due to the fact that they contain more vegetable, market yard hotel wastes and wastes generated from residential areas of the city as compared to Amberpet and Autonagar wastes. Mutatkar (1985) reported that the organic carbon content of Indian city refuse varied from 12.0 to 15.30. Nandkishore (1980) reported organic carbon content of Bangalore city waste compost as 9.42 per cent. Olaniya and Saxena (1977) reported organic carbon content of 18.90 per cent for Jaipur city refuse. Patel and Tiwari (1990) reported organic carbon from 19.80 to 33.80 per cent for Rourkela industrial city waste.

King et al. (1974) reported organic carbon content of Ontario refuse as 37.00 per cent. Talashilkar and Vimal (1985) reported organic carbon content of Delhi city compost as 14.50 per cent. Bhide and Muley (1973) reported organic carbon content for Nagpur city refuse as 18.87 per cent. Gupta et al. (1984) reported that the organic carbon content of Calcutta city wastes ranged from 8.50 to 10.00 per cent. Gupta et al. (1986) reported organic carbon content of Calcutta city waste composts range from 7.20 to 7.80 per cent. Ramachandran and D'Souza (1990) reported organic carbon content of Bombay city wastes as 10.40 per cent. The organic carbon content varies with the source of collection of urban solid wastes. The content of

organic matter in solid wastes is very critical to evaluate its suitability for composting. Higher the organic carbon content better is the waste for composting and subsequent use as manure. In this respect the Golkonda solid wastes are more suitable for treatment through composting than Amberpet and Autonagar wastes.

The free CaCO_3 ranged from 5.00 (AFW) to 7.70 (ASW 1) per cent which is influenced largely by the content of fine earth and ash in the urban solid wastes (Tables 17 and 19).

5.1.2.2 Chemical properties: The data are presented in Tables 17 to 25.

The CEC of wastes ranged from 50.00 (AFW) to 151.0 Cmol (P+) kg^{-1} waste (GSW). The variation in CEC is largely contributed by the organic matter content, its degree of decomposition and content of fine earth and ash in urban solid waste.

The organic matter in wastes ranged from 5.80 (AFW) to 10.90 per cent (GSW). This is considered to be low when compared with reported organic matter contents of wastes of a few other Indian cities. Bhide and Muley (1973) reported organic matter content of Nagpur city refuse as 32.54 per cent. Olaniya and Saxena (1977) reported 32.80 per cent of organic matter for Jaipur city (India) refuse, whereas Patel and Tiwari (1990)

reported 34.20 to 58.30 per cent organic matter with Rourkela city wastes. Mutatkar (1985) reported the organic matter content of Indian city refuse ranged from 20 to 30 per cent. It varied with all the parameters that affect the physical composition of the urban solid wastes. The lower organic matter content of the Hyderabad city wastes is probably due to salvaging of waste components like paper and rags and also because of high content of fine earth and ash which reach the wastes through sweepings from streets and homes.

The chemical oxygen demand of Hyderabad city wastes ranged from 89.0 (AFW) to 168.0 (GSW 2) mg g^{-1} . Olaniya and Saxena (1977) reported C.O.D. as 528 mg g^{-1} for Jaipur city waste. Nandkishore (1980) reported C.O.D. values of Bangalore city waste compost as 278.0 mg g^{-1} . This parameter is largely dependent on organic matter content and its extent of decomposition in the urban solid waste. The C.O.D. estimates help in evaluating the maturity of refuse during composting. In fresh wastes, the C.O.D. content will be more than the stabilized wastes because of the extent of decomposition of organic matter in stabilized wastes.

The total nitrogen content ranged from 0.1 (AFW) to 0.50 per cent (ASW 2) in fresh as well as stabilized solid wastes respectively (Table 20). Olaniya and Saxena (1977) reported total nitrogen

content of 0.67 per cent in Jaipur city wastes. Bhide and Muley (1973) reported N content of Nagpur city refuse as 0.697. Nandkishore (1980) reported N content of Bangalore city waste compost as 0.58 per cent. Mutatkar (1985) reported the N content of Indian refuse varied from 0.56 to 0.62 per cent. Patel and Tiwari (1990) reported total N content of 0.49 to 0.87 in Rourkela solid wastes. Gupta et al. (1984) reported total nitrogen content of 0.60 per cent in Calcutta city wastes. Gupta et al. (1986) also reported total nitrogen content of 0.63 to 0.69 per cent in Calcutta city waste composts. Nitrogen in wastes is largely contributed by the organic matter fraction and is therefore directly proportional to the organic matter content of wastes.

The total phosphorus content of wastes ranged from 0.14 (ASW) to 0.84 per cent (GSW), whereas it ranged from 0.43 to 1.67 per cent in Rourkela city wastes (Patel and Tiwari, 1990). Talashilkar and Vimal (1985) reported total P content of Delhi city waste compost as 0.26 per cent. Olaniya and Saxena (1977) reported P values of 0.62 per cent in Jaipur city refuse. Gupta et al. (1986) reported total P content of Calcutta city waste composts as 0.28 to 0.31 per cent. Bhide and Muley (1973) reported total P content of Nagpur city refuse as 0.867 per cent. Mutatkar (1985) reported the P content of Indian city refuse varied from

0.60 to 0.72 per cent. The main source of P in USW is the organic matter and other inorganic materials like fine earth, metals, ash, rubber and other components containing P.

The total potassium content in Hyderabad city wastes ranged from 0.19 (AFW) to 0.46 per cent (GSW 1). Bhide and Muley (1973) reported total K_2O content of Nagpur city refuse as 0.842 per cent. Olaniya and Saxena (1977) reported values of 0.70 per cent for Jaipur city refuse. Mutatkar (1985) reported the K content of Indian city refuse varied from 0.60 to 0.72 per cent. Gupta et al. (1986) reported total K content of Calcutta city waste composts as 1.67 to 2.79 per cent. Talashilkar and Vimal (1985) reported total K content of Delhi city waste compost as 0.70 per cent. The main sources of K in wastes are organic and inorganic materials like soil, fine earth, ash, vegetable matter, metals and other components.

The total calcium and magnesium contents of wastes ranged from 0.50 (AFW) to 0.75 (ASW 3) and 0.12 (AFW) to 0.21 per cent (ASW) respectively. The main source of these two elements is organic matter and fine earth, ash and other components.

The total sodium content of wastes ranged from 0.10 (AFW) to 0.24 per cent (GSW). Gupta et al. (1984)

reported total Na content of Calcutta city wastes as 0.30 to 0.38 per cent. The sources for this element are organic matter fine earth, ash and inorganic salts. The Na content of urban solid wastes should be carefully monitored and management practices should be followed that will keep the Na content of the wastes as low as possible, particularly if the wastes are being used as manure either fresh or after composting.

The water soluble ions in wastes like K^+ , Na^+ , SO_4^{2-} and Cl^- ranged from 1240 (AFW) to 2660 (GSW 2), 530 (GFW) to 2400 (GSW), 910 (AFW) to 3030 (GSW 1) and 660 (ASW 2) to 1000 (GSW) ppm respectively (Table 21). Jaipur city waste contained 6750.0 ppm water soluble sulphate and 1800.0 ppm chlorides (Olaniya and Saxena (1977)). The urban solid wastes usually carry high amounts of soluble salts. Potassium and sodium in the wastes are highly soluble and readily get leached. However, divalent cations like Ca^{++} and Mg^{++} are prone to leaching and more comparatively slowly in the wastes or in soils. Part of the salts in organic wastes is not soluble initially but gets solubilized during decomposition of wastes at the landfill sites, during composting operation or on land when applied directly as manure.

The C/N ratio of refuse ranged from 12.23 (ASW 2) to 36.00 (GFW). In Jaipur city waste, the C/N ratio

was 28.2 (Olaniya and Saxena, 1977). Bhide and Muley (1973) reported C/N ratio for Nagpur city waste as 27.02. Nandkishore (1980) reported C/N ratio of Bangalore city waste composts as 16.24. In Rourkela city waste, it ranged from 24.50 to 61.10 (Patel and Tiwari, 1990). Mutatkar (1985) reported the range of C/N ratio for Indian city refuse as 25 to 35. This characteristic gives an idea about the maturity of wastes. In general, the C/N ratio is higher in fresh wastes than in stabilized city wastes. Wastes with lower C/N ratio of less than 40 : 1 are preferable to be used in agriculture, otherwise crop growth is affected due to the imminent nitrogen immobilization when wide C : N ratio urban solid wastes are applied to land. In this respect, the urban solid wastes generated in Hyderabad appear to possess an agreeable C : N ratio. It also indirectly indicates that the garbage may contains protenaceous wastes in larger proportion.

The total micronutrient and heavy metal contents of Hyderabad city wastes ranged from ~~pe~~-2950.00 (AFW) to 9026.30 ppm (ASW 2) and the ranges of different micronutrients were:

	284.00 (AFW) to 579.60 ppm
(ASW 2) manganese,	124.00 (AFW) to 426.00 ppm (ASW)
zinc,	82.00 (AFW) to 143.00 ppm (ASW)
copper,	88.00 (AFW) to 180.00 ppm (ASW)
lead,	8.50 (AFW) to 18.96 ppm
(GSW 2) ppm nickel,	4.63 (ASW 1) to 6.00 ppm (GFW and ASW)
cobalt,	16.00 (GSW) to 30.00 ppm (GFW and ASW)

chromium and 1.00 (GSW) to 3.00 ppm (ASW) cadmium in fresh and stabilized urban solid wastes on dry weight basis (Tables 22 and 23). The sources of micronutrients and heavy metals in wastes are metals, printed paper, rubber fine earth ash and organic materials.

The total iron content in wastes was highest while total cadmium content was the lowest among all the total trace metals studied. These trace metals may be obtainable in USW from organic and inorganic components (Table 1).

Talshilkar and Vimal (1985) reported total micronutrient contents of Delhi city waste compost as Zn 400, Mn 77, Cu 210 and Fe 8500 ppm. King et al. (1974) reported the total trace element contents of Ontario, Canada city refuse as manganese 250, copper 28, zinc 400, lead 200, cadmium 7 and chromium 31 ppm. Cottrell (1975) reported total trace metal content of Washington city refuse as Fe 9250, Mn 286, Cu 334, Zn 615, Co 2.9 and Cr 17.0 ppm whereas Ramachandran and D'Souza (1990) reported total chromium as 51 ppm and total manganese as 622 ppm in Bombay city waste composts. Gupta et al. (1984) reported that the total cadmium content of Calcutta city wastes ranged from 4 to 10 ppm. Trace elements in organic wastes were less soluble and migrate more slowly than Na and K. Utilization or disposal of city refuse on land adds to the

trace element load in the eco-system. In general, the trace element load is higher in urban solid waste than in normal agricultural soils. Many reports from India or abroad indicate that of the micronutrient and heavy metal iron content is more than others.

The DTPA-extractable micro-nutrients and heavy metals in Hyderabad city wastes ranged from, iron 23.00 (ASW) to 63.00 (GFW), manganese 12.66 (ASW 2) to 25.00 (GSW), zinc 28.00 (AFW) to 42.66 (ASW 1), copper 27.00 (AFW) to 35.66 (GSW 1), lead 20.00 (ASW) to 34.00 (GSW), Nickel 2.00 (AFW and ASW) to 3.10 (GSW), cobalt 0.25 (AFW and GFW) to 3.00 (GFW and ASW), chromium 0.30 (GSW) to 0.80 (GFW and ASW), cadmium 0.10 (AFW) to 0.18 (ASW) ppm in fresh and stabilized wastes (Tables 24 and 25). The highest concentration of DTPA-extractable trace element was iron and lowest was cadmium in wastes but the relative availability of these metals is very important than the DTPA-extractability. In Calcutta city wastes (fresh) the DTPA-Zn and Fe were more than other trace elements (Gupta *et al.*, 1984), whereas in Calcutta city waste composts, the DTPA extractable micronutrients ranged from Fe 84 to 90, Zn 144 to 150, Cu 24 to 30 and Mn 30 to 38.4 ppm (Gupta *et al.*, 1986). In Bombay city wastes, the DTPA-extractable micronutrients like manganese and chromium were 45 ppm and traces respectively (Ramachandran and D'Souza, 1990).

The Cd/Zn ratio (per cent) in city wastes was 0.42 (ASW 2) to 1.70 (AFW) in fresh and stabilized wastes (Tables 17 and 25). Chaney (1973) suggested that maintaining low (< 0.5 per cent) Cd/Zn ratio in wastes to be applied to agricultural land will ensure against contamination of the food chain by Zn or Cd.

An examination of the data on relative DTPA-extractability of metals in wastes showed that the Cu, Ni, Pb and Zn were relatively more extractable than others (Tables 26 to 28), whereas Cr and Fe were least extractable among all the trace elements studied. Mortvedt and Giordano (1975) suggested that lower recoveries of some trace elements with DTPA are probably due to this extractants inability to compete with organic ligands.

An effective monitoring system that measures concentration of a very large number of elements in urban solid wastes is essential for their use in food crop production.

5.2 IMPACT OF URBAN SOLID WASTE DISPOSAL ON SOIL CHARACTERISTICS AT AMBERPET LANDFILL SITE

The results of the research work carried out on impact of waste disposal on soil characteristics at Amberpet landfill site, as described in the preceeding chapter, are discussed in the following paragraphs.

The results obtained showed that the sand content decreased, silt and clay contents increased in all the profiles as compared to control. The increase in clay and silt contents to a certain depth is clearly indicative of mechanical illuviation having taken place due to the migration of clay and silt with water moving down from the waste heaps to the soil profile. The USW had higher content of earth and ash. Water percolating through the waste profile carried silt and clay to the soil profiles and deposited them at different depths depending on the intensity of leaching and runoff in case of profiles A and B. Consequently the soil is getting altered to a heavier texture (Table 33).

The soil colour has also been subjected to a significant change in some depths due to downward movement of leachate through soil profiles. The soil colour is a function of organic carbon, iron and manganese oxides and a change in these constituents will affect the soil colour to a greater extent. The colour change could also be partially attributed to mechanical illuviation taking place leading to significant downward movement of silt and clay fraction (Table 34).

The soils of all the profiles under USW and runoff affected were alkaline in reaction as compared to control, and the mean pH ranged from 7.80 (control) to

9.94 (profile A). The increase in alkalinity appears to be largely due to movement of soluble sodium and CaCO_3 into the soil. Winant et al. (1981) also reported such changes in soil pH at different soil depths due to urban solid wastes in soil. Similarly Otsuka and Adachi (1980), Kowaed et al. (1982) and Schossing (1983) observed that application of town refuse compost to soil increased the pH. Petruzzelli et al. (1989), investigating on the soil treated with compost for four years continuously, reported that soil pH increased by 0.50 units.

The EC of soils varied from 0.09 (180-210 cm in profile C) to 10.86 d S m^{-1} (90-120 cm in profile 4). A part of the precipitation which ultimately reaches the water table below the soil profile tends to be higher in salts concentration due to dissolution of salts. Accumulation of salts in the soil from waste application will invariably result in downward leaching of salts into the zone of saturation. The high rates and extended intervals of application of organic solid wastes exerts a severe strain on the capacity of the soil to bear the load of soluble organic and inorganic constituents of the USW.

Soluble salts leach more rapidly from wastes. Some salts of potassium and sodium in the wastes are highly soluble and, therefore, get readily leached.

Part of the salt in organic wastes is reported to be not soluble initially but is released during decomposition of the waste. According to King et al. (1974), the electrical conductivity of soil increased with application of refuse. Petruzzelli et al. (1989) reported an increase in electrical conductivity from 0.07 S m^{-1} upto 0.20 S m^{-1} with highest addition ($30 \text{ t ha}^{-1} \text{ yr}^{-1}$) of refuse compost.

In the present study, it was observed that the soluble pollutants were concentrated more in soil depths where clay content was more and then decreased with the depth. The EC was greater than 4.0 d S m^{-1} at certain soil depths and, hence, could be categorised as saline.

The CEC values of the soils showed a wide variation ranging from 1.6 (180-210 cm in profile C) to $21.0 \text{ Cmol (P+) kg}^{-1}$ soil (120-150 cm in profile A). The higher CEC in the soil depths is due to the accumulation of clay which moved from the wastes. Hortenstine and Rothwell (1969) and Murillo et al. (1989) reported that the application of refuse increased CEC of soils. Winant et al. (1981) reported that the CEC increased from 21 to $30 \text{ C mol(p}^+) \text{ kg}^{-1}$ soil at the 0-5 cm soil depth due to application of leachate and this was attributed to organic chelation. Hence, increase in CEC of surface soils due to dumping of wastes may be attributed to increase in organic matter content.

The per cent base saturation of the soils varied from 44.7 to 98.88. The dominant cation on the exchange complex of soil profiles 1 to 4 and in profile C under investigation was Ca^{++} followed by Mg^{++} , K^+ and Na^+ whereas in runoff affected soil profiles A and B, the dominant cations on the exchange complex were Na^+ , Ca^{++} , Mg^{++} and K^+ . In profile A, the Na^+ was dominant and replaced Ca^{++} and Mg^{++} completely at 150-210 cm depth which is because of a relatively greater mobility of Na^+ coupled with exclusion of Ca^{++} , Mg^{++} and K^+ . The ESP of soils ranged from 0.27 (90-120 cm in profile C) to 70.6 (0-30 cm in profile A). In profile A, the ESP was more than 15 per cent at all the depths, hence, were alkali in nature. Winant et al. (1981) reported that the application of leachate increased Ca and Mg upto 30 cm depth and doubled the amount of extractable K in the soils. Such a hazard was not evident from the data obtained for control profile C. This is possibly due to adsorption processes (Griffin and Shimp, 1976 and Farquhar, 1977). They reported further that the exchangeable Na levels increased four fold over the control values f i.e., 25 ppm to 108 ppm at surface and 14 ppm to 100 ppm at 30.0 cm depth of soil.

The organic carbon content of the soil samples varied from 0.001 (180-210 cm in profile C) to 1.50 per cent (0-30 cm in profile 2) and decreased as soil depth

increased. The organic carbon content increased in all the depths as compared to control. This increase is due to addition of wastes in soil. Murillo et al. (1989) reported that application of urban waste compost increased organic matter in the top 0-10 cm soil and at a depth of 12-22 cm following applications of 150 and 400 t compost per ha. Kowaed et al. (1982) reported that the application of refuse compost increased the carbon content of the soil from 1.25 to 1.59 per cent. The increase in organic matter content at lower depths of the soil profile is due to migration of soluble and particulate organic matter through water.

In soil profiles 1 to 4, the free CaCO_3 increased due to disposal of wastes on soil whereas in runoff affected soil profiles i.e., profiles A and B due to excess Na, the Ca^{++} was replaced in the soil samples and decreased free CaCO_3 to nil at 150-210 cm depth.

The total nitrogen content of the soil profiles followed the pattern of organic carbon content, lowest values were observed in control. According to Winant et al. (1981), total-N content increased in the soil upto 15 cm depth when leachate was added.

In all the samples an increase in contents of available N, P and K was evident as compared to control which decreased with increase in soil depth (Table 37).

Winant et al. (1981) reported that application of leachate increased available N, P and K contents of soils. Sotomayor (1979), Schossing (1983), Kowaed et al. (1982) and Giusquiani et al. (1988) reported that the application of refuse composts increased available N, P and K contents of soils several folds.

The water soluble ions like K^+ , Na^+ , SO_4^{2-} and Cl^- increased several folds as compared to control (Table 38) in all the soil profiles studied. The water soluble potassium increased from 2.5 (180-210 cm in profile B) to 6010.0 ppm (90-120 cm in profile 4), sodium from 5.0 (0-30 cm in profile C) to 6750.0 ppm (90-120 cm in profile 4), sulphate from 4.0 (180-210 cm in profile C) to 7930.0 ppm (90-120 cm in profile 4) and chloride from 2.5 (180-210 cm in profile 4) to 3672.0 ppm (90-120 cm in profile 4). The water percolating through the solid wastes carries water soluble ions and enters soil column, where these ions exchange with other ions, and concentrate at a particular depth depending on clay and silt contents. It is evident from the increase in EC values that some soils may become saline due to accumulation of soluble salts when treated with USW.

The total Fe, Mn, Zn and Co contents of soil profiles studied decreased as compared to control (Tables 39 and 40) whereas Cu, Pb, Ni, Cr and Cd contents increased. Chain and Dewalle (1976) reported

lower concentrations of Mn and Zn in leachate. The levels of Cu, Pb and Cd increased in landfill leachate in both the studies of Chain and Dewalle (1976) and Winant et al. (1981).

The total manganese and zinc contents in soils studied increased as soil depth increased. Jalali et al. (1989) also have reported that the total micronutrient contents were influenced by soil properties like pH, organic carbon, clay and CaCO_3 contents. The total copper content decreased with increase in soil depth. The clay fraction gets enriched with metals compared with the other textural components sand and silt and is the largest reserve of micronutrient and heavy metals.

The DTPA-micronutrients in soil profiles 1 to 4 and A and B increased as compared to control (Table 41) and followed the order; $\text{Mn} > \text{Fe} > \text{Cu} > \text{Zn}$. Similar results were reported by Schossing (1983), Murrillo et al. (1989) and Giusquiani et al. (1988).

The DTPA - Pb, Ni and Co contents of all the soil profiles increased over control (Table 42), whereas Cd and Cr could not be detected. Similar results were also reported by Gray and Biddlestone (1980).

The results pertaining to impact of waste disposal on soil properties at Amberpet landfill site clearly indicates that the major soil pollutants causing

concern are increased accumulation of soluble salts and sodium, which are the twin hazards often encountered. Excessive accumulation of salts adversely affects the germination and growth of crops. High Na levels and K, to a lesser degree, cause dispersion of soil particles, poor soil structure and reduced infiltration rates (Agarwal et al., 1982). Though landfill sites cannot be used for normal agricultural activities, the pollution hazards will be experienced more in respect of ground and surface water, which are mobile and cause serious problems.

Indian Standards Institution Guidelines for selection of methods of urban solid waste disposal IS-9533:1980 describes various methods of disposal of USW. The guidelines also give the advantages and disadvantages of these methods on the basis of which a suitable method can be advocated in a specific given situation.

In the present investigation the landfill sites were chosen to study their impact on soil pollution. The sanitary landfilling as given in ISI-9533:1980 standards have the following advantages when compared with other methods.

- a) The process can be made sanitary.
- b) Highly skilled personnel are not needed.

- c) It can be safely over loaded without causing any problems.
- d) It converts low lying marshy waste land to useful areas having a resale value.
- e) Natural resources are returned to soil and recycled.
- f) Stabilized material may be excavated and reused, if necessary, and then the land may again be used for filling.
- g) This has been found to be the cheapest method of disposal in India.

Besides, above advantages, the following steps to be followed in site selection for disposal of USW.

- i) Determine kind of waste and method of disposal or utilization.
- ii) Assess the soil properties and select criteria to determine the suitability of soil for receiving the wastes in question.
- iii) Using soil surveys, determine which soils in the area are suited for receiving wastes.
- iv) Locate the suitable soils on the soil map to determine extent of potential sites.

Inspite of these well meaning recommendations and suggestions, the fact remains that in the disposal of USW the crucial aspect to be considered is the impact of landfill disposal on ground and surface water quality. These two sources of water have the potential to cause severe problems as there is a distinct possibility of such waters being used for agriculture and for drinking and other purposes. The pollutants in such water may directly affect plant growth as is the case with water having high salt contents of toxic organic and inorganic constituents. Otherwise the toxic constituents may enter the food chain through drinking water.

5.3 METHDOLOGY FOR DETERMINING THE ACCUMULATION OF PLANT GRWOTH INHIBITORS IN SOIL DUE TO DISPOSAL OF URBAN SOLID WASTES OR LANDFILL RUNOFF

The disposal of solid wastes in landfills or the direct application of fresh or composted urban solid wastes on land for cultivation of crops might cause several effects. Primarily these effects are related to the dissolution and movement of soluble constituents contained in USW with the movement of water through the wastes into the soil profile. The soluble components can be either organic or inorganic and depending on their solubilities in water, may get concentrated in different horizons or depths within a soil profile. To obtain information on accumulation of such compounds

which might have different influences on living systems it is essential to develop a simple procedure to ascertain such an impact in a reasonably short period of time. With this in view, a bioassay was conducted using the seeds of Setaria italica (Italian millet) which is relatively more tolerant to high salt concentration. The seeds were sown in soil samples collected from different depths at the landfill site in Amberpet where USW have remained deposited over the soil for almost three decades. A soil profile in the proximity of the landfill site where USW have not been deposited served as experimental control. The data on dry matter yield of Italian millet are presented in Table 43.

An examination of the data revealed that the maximum dry matter yield recorded was $1255.0 \text{ mg dish}^{-1}$, at 30-60 cm depth soil collected from profile 2. This may be due to the enrichment of nutrients and growth promoting substances contained in the USW in that particular depth. In soil samples where EC was more than 10.0 d S m^{-1} (profile 4 at 60 to 120 cm) and with highest ESP which ranged from 42.4 to 70.6 (in soil profile A) the Italian millet failed to germinate. This indicates that due to urban solid waste disposal on land at landfill sites the soil underneath is prone to serious salinity and alkali hazards. The problem appears to be both due to high salt and sodium accumulations in profile at certain depths. In fact these

landfill soils cannot be used for normal agricultural purposes and also will definitely pose a threat to ground and surface water pollution due to gradual downward movement of wastes constituents from the soil profile to groundwater aquifers.

According to Hortenstine and Rothwell (1969) and Cunningham et al. (1975) the presence of soluble salts and/or organic materials resulted in decreased germination and emergence of seeds of several crops planted in soils treated with sewage sludge, animal waste or compost. The saturation extracts of mixtures of soil and urban refuse compost depressed the germination of barely, perennial rye grasses, bean and tomato (Nogales et al., 1984).

This bioassay procedure, therefore, is effective in identifying the accumulation of seed germination and plant growth inhibiting or promoting factor in soils. It enables the location of the soil depth where concentration of such germination and growth inhibiting or promoting factors accumulated due to downward movement of leachate through soil profile at a landfill site. The method can be employed as a preliminary step in environmental impact assessment due to disposal of USW as landfill.

5.4 CHARACTERISTICS OF WATERS FROM LANDFILL SITES

5.4.1 Characteristics of runoff water from Amberpet Landfill site

The control of onsite runoff and transport of chemicals in solution and solids in suspension are of major importance in the design of proper treatment procedures for disposing USW in large urban surroundings.

The universal soil loss equation (Smith and Wischmeier, 1962) indicates soil erosion is a function of rainfall, soil properties, slope length and steepness, cropping sequence and supporting practices. Practices to minimize erosion will likewise control onsite runoff and pollutant transport. If runoff is expected from a disposal site, the quality must be within acceptable limits for immediate discharge to a receiving stream or water course. At the Amberpet landfill site, which is area of study of the present investigations, it was found that no proper precautionary measures have been taken to prevent runoff from the landfill site. Consequently significant runoff of water occurred leading in flow of water from the landfill to the wells surrounding the site. It is also distinctly possible that in addition to surface runoff, water from the landfill site may reach the wells by seepage. In view of this existing situation, the quality of runoff water from the landfill site was monitored. The pH of the

runoff water ranged from 8.3 to 8.8 i.e., alkaline, electrical conductivity from 0.15 to 0.182 d S m⁻¹ dissolved CO₂ from 0.3 to 0.72 mg l⁻¹, turbidity 1.4 to 2.1 NTU whereas the total solids ranged from 14.7 to 181.0 mg l⁻¹ showing the need for controlling the runoff. Other chemical parameters like K, Na, Cl⁻, SO₄⁼ and trace elements (Tables 44 and 45) were found in considerable quantities. Eventhough the runoff water characteristics studied were within the tolerance limits prescribed by Indian Standard Institution (IS-2296:1982) for inland surface waters subject to pollution. There is a need to control runoff from landfill sites to avoid ground water and surface water contamination in the long run. The landfill runoff water can also pollute the soil nearby.

The use of urban storm runoff water for recharge has received attention not only for conservation purposes, but also for its chemical constituents and their impact on the ground water quality and surface soils (USEPA, 1983 and Nightingale, 1987). The major cations present in urban residential storm runoff are Na⁺, K⁺, Ca²⁺ and Mg²⁺ (Nightingale, 1989).

The findings of present study are relevant because of the information generated on the quality of landfill runoff and its effect on soil and on chemical constituents of ground and surface waters.

The Amberpet landfill site is more than 20 years old and addition of fresh wastes has been abandoned since 1983.

The study of runoff water quality indicated that the control of runoff waters from this old landfill site is essential to prevent pollution of ground and surface waters and soils in the vicinity due to dissolved constituents.

5.4.2 Characteristics of well waters located in the proximity of landfill sites ✓

The ground water contamination around the refuse dumps is mainly through the leaching from USW refuse layer accumulating over the soil surface. The actual degree of pollution could be assessed by determining the important parameters like total dissolved solids, total hardness, chlorides, cations and COD in the water. By following the path of the leachate as it percolates through the soil and studying the changes in the quality of the leachate, the degree of pollution with reference to distance percolated could be ascertained. Leachate from tipped refuse is stronger than sewage at the time of formation in terms of chemical characters. During the percolation of leachate through soil, it becomes weaker due to the physical, chemical and biological changes before it contaminates the ground water and, hence, the importance of the distance.

Results of the analysis of physical, physico-chemical and bacteriological characteristics of well water obtained from located at different distances from the landfill are presented in Tables from 46 to 50. The recommended limits of Indian Standard Institution (ISI, 1982 and 1983), Indian Council of Medical Research (ICMR, 1975) and WHO (1984) are given in Table 73. It can be seen from the results that the mean temperature of well waters ranged from 25.16 to 27.33°C for Golkonda and Amberpet (monsoon) samples, respectively. The temperature depends on terrestrial heat, exothermic and endothermic reactions in rocks, infiltration of surface water, insulation, thermal conductivity of rocks, rate of movement of ground water and interference of man on the ground water region (Karnath, 1987). The temperature of water has an influence on its taste. Olaniya and Saxena (1977) reported well water temperature as 20-24°C while studying the pollution of ground water by open refuse dumps at Jaipur.

The pH of the water samples indicates the form in which CO₂ is present in the water. The pH of the water samples collected from wells ranged from 7.1 to 8.1 at Golkonda and 8.46 to 8.64 at Amberpet, thereby, indicating that the well waters were alkaline. Similarly Olaniya and Saxena (1977) reported that the pH of well waters, ranged from 7.2 to 8.4 while studying the

Table 73 : Standards for potable and irrigation water proposed by different organisations

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S.No.	Substance or characteristic	Unit	ISI:10500, 1983	ICMR, 1975	WHO, 1984	Irrigation ISI:229: 1982 (Class-E)

1	pH	--	6.5 to 8.5	7.0 to 8.5	6.5-8.5	6.0 to 8.5
2	Conductivity 25°C-Max	μSm^{-1}	--	--	--	2.25
3	Turbidity	NTU	10.0	--	5.0	--
4	Dissolved oxygen (as O_2)-Min	mg l^{-1}	6.0	--	--	--
5	Total dissolved solids - Max	mg l^{-1}	500	--	1000	2100
6	Total solids	mg l^{-1}	--	1000	--	--
7	Total Hardness (as CaCO_3)-Max	mg l^{-1}	300	--	500	--
8	Ca-hardness (as CaCO_3) - Max	mg l^{-1}	200	--	--	--
9	Mg-Hardness (as CaCO_3) - Max	mg l^{-1}	100	--	--	--
10	Chlorides (as Cl)- Max	mg l^{-1}	250	250	250	600
11	Sulphate (as SO_4) - Max	mg l^{-1}	150	250	400	1000
12	Nitrate (as NO_3)- Max	mg l^{-1}	45	--	10	--
13	Fluoride (as F)	mg l^{-1}	0.6-1.2	--	1.5	--
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Contd...

ground water pollution by open refuse dumps at Jaipur. The pH does not have any adverse effects on health but affects the mucous membrane and it alters the taste quality of water. Higher pH reduces the germicidal potentiality of chlorine and induces the formation of toxic trihalomethanes (Trivedy and Goel, 1986). Almost all the water samples had higher pH values in the present investigation, however, most of the pH values are within the recommended limits of ISI (1983), WHO (1984) and ICMR (1975). The pH of well waters at Amberpet landfill site was more than of Golkonda which is probably due to the fact that Amberpet landfill site is older than the Golkonda site and, hence, has received USW for a longer period of time. The electrical conductivity of well waters ranged from 0.9 to 2.2 and 2.5 to 3.8 d S m^{-1} in Golkonda and Amberpet (summer) sites, respectively. The electrical conductivity is mainly due to the dissolved ions such as bicarbonates, chlorides, sodium, potassium, magnesium and sulphate (Peavy et al., 1986). The electrical conductivity of all the well waters including bore wells were beyond the prescribed limit of ISI (1982) regulations for irrigation indicating the unsuitability of water for irrigation and drinking. The increase in conductivity is due to leachate infiltration from urban solid wastes (Carlsson, 1977).

The turbidity of all the well waters were within the recommended limits of WHO (1984) and ISI (1983) i.e., 5 and 10 NTU, respectively. Turbidity is caused by wide variety of suspended matter which ranges in size from colloidal to particulate matter and cause dispersion depending upon the degree of turbulence. Turbid waters are undesirable from aesthetic point of view in drinking water supplies. Above the standard limit consumer acceptance decreases (NEERI, 1987).

The total solids content of well waters ranged from 800 to 2400 and 2000 to 3500 mg l^{-1} to Golkonda and Amberpet (summer) landfill sites respectively. At Amberpet site it increased in summer than in monsoon. It is because, in summer generally water level recedes and in this process, the contents of total solids or both soluble and insoluble constituents increases. The total solids concentration in well waters at Amberpet site was more than in the well water of Golkonda which is related to the age of the landfill site, Amberpet being the older one. In some wells, the total solids concentration in water exceeded the permissible limits proposed by ICMR showing that the waters are polluted. The total solids in all the wells at both the sites decreased with increase in the distance of wells from the landfill sites. The well waters upto the distance of 150 and 200 meters were very much polluted in Golkonda and Amberpet sites respectively. Wells located

at a distances more than 200 meters appeared to contain less load of pollutants in terms of total solids and other pollution - causing indicators. Similar results were reported by Olaniya and Saxena (1977).

The total dissolved solids concentration of well waters was more at Amberpet than at Golkonda sites, where it is found to be as high as 2800 mg l^{-1} . Similarly Olaniya and Saxena (1977) reported that the total dissolved solids contents of well waters ranged from 1320 to 2136 mg l^{-1} by open refuse dumps at Jaipur whereas Nicholson et al. (1983) reported TDS content of 4000 mg l^{-1} in well waters at a landfill site in Ontario, Canada. However, at Golkonda site, two wells 5 and 6 had the total dissolved solids content near the permissible value of 500 mg l^{-1} . The two wells 1 and 2 at Golkonda site and all the wells at Amberpet site during summer showed total dissolved solid content higher than the limit of 500 mg l^{-1} prescribed by ISI (1983) whereas WHO (1984) had stated 1000 mg l^{-1} as the upper limit for drinking water.

According to ISI (1982) class E standards, well waters containing total dissolved solids more than 2100.0 mg l^{-1} are not suitable even for irrigation. Beyond the limit of 500 mg l^{-1} the palatability of water decreases and may cause gastro intestinal irritation in animal and man when consumed.

The concentration of total suspended solids followed the same pattern of change as that of total dissolved solids and ranged from 206.0 to 621.0 and 340.0 to 700.0 mg l^{-1} in Golkonda and Amberpet (summer) samples, respectively. Waters with very high levels of suspended solids may be aesthetically disagreeable unsatisfactory for such purposes as bathing. The suspended solids correspond to non-filtrable residue. The chemical and physical nature of material in suspension, the pore size of the filter used for its estimation, the area and thickness of the filter mat, and the amount and physical state of the materials deposited on it are the principal factors affecting the suspended solids.

Surface waters normally contain less than 10 mg l^{-1} free CO_2 , while some groundwaters may easily exceed that concentration. The CO_2 content of a water may contribute significantly to corrosion. The results of the study showed that the dissolved or free CO_2 ranged from 1.4 to 10.0 and 3.2 to 18.5 mg l^{-1} in Golkonda and Amberpet (summer) well waters respectively. The free CO_2 in all the well waters was found to be in the acceptable range with reference to the prescribed standards (Table 73).

Hardness of water is not a specific constituent but is contributed by a variabal and complex mixture of

cations and anions. The prominent hardness causing ions are calcium and magnesium. The results showed that the total hardness in well waters ranged from 200 to 874 and 620 to 1260 mg l^{-1} of Golkonda and Amberpet (summer) landfill sites respectively. Similarly Olaniya and Saxena (1977) reported that the total hardness of well waters ranged from 140 to 980 mg l^{-1} by open refuse dumps at Jaipur. Values of total hardness were above the prescribed limit of 300 mg l^{-1} ISI (1983) and 500 mg l^{-1} WHO (1984) in four samples of Golkonda and all the samples in monsoon and summer at Amberpet landfill site. However, the quantities of Ca and Mg hardness in four samples of Golkonda and all the Amberpet samples were higher than ISI Standards (1983). Hard water is unsuitable for domestic purposes. High concentration of magnesium combined with sulphate act as laxative to human beings and it may cause encrustation in water supply structures. The total hardness showed decrease in its value with increase in the distance of wells from landfill sites. Similar results were reported by Olaniya and Saxena (1977).

Hardness of water may also be interpreted in terms of carbonate (temporary) and non-carbonate (permanent). Carbonate hardness can be removed or precipitated by boiling. This type of hardness is responsible for the deposition of scale in hot water pipes and cooking and water heating gadgets. Non-carbonate hard-

ness is caused by the association of hardness causing cations with sulphate, chloride or nitrate. It cannot be removed by boiling. Public acceptability of the degree of hardness may vary considerably from community to community depending on local conditions. The results showed that the carbonate hardness ranged from 200 to 874 and 620 to 1260 mg l^{-1} in Golkonda and Amberpet (summer) well water samples respectively and non-carbonate hardness was found to be not prevalent in Golkonda and Amberpet (summer) water samples. Olaniya and Saxena (1977) reported that carbonate hardness of well waters ranged from 140 to 980 mg l^{-1} and non-carbonate hardness ranged from nil to 168 mg l^{-1} by open refuse dumps at Jaipur.

Dissolved oxygen (DO) levels in natural and waste waters are dependent on the physical, chemical and biological activities prevailing in the water body. For a diversified warm water biota, the dissolved oxygen (DO) concentrations must be atleast 5 mg l^{-1} . For a cold water biota DO concentrations at or near saturation values are desirable. The minimum level must be not lower than 6 mg l^{-1} . The amount of DO at saturation varies with water temperature and altitude (Chhatwal et al., 1989). The data obtained in the present study reveal that the DO in well waters ranged from 4.6 to 7.4 to 3.7 to 7.4 of Golkonda and Amberpet (summer) landfill

sites respectively. The lowest DO values, below 5 mg l^{-1} were observed in wells nearest to the landfills at both Golkonda and Amberpet indicating possibilities of pollution of these wells with increased content of decomposable organic matter. The presence of organic matter in water bodies found to decrease the available oxygen in a given system. Four major reasons are recognised which reduce the oxygen levels within a given system (Chhatwal et al., 1989) viz., (1) decreasing the photosynthetic rate of plants in waters (2) decreasing in the solubility of the oxygen within the water body (3) Interference with the diffusion of atmospheric oxygen at the air-water interface and (4) increasing in oxygen consumption of the aerobic microbial biota of the system.

The coliform bacteria includes all of the aerobic and facultative anaerobic gram negative, non-spore forming rod shaped bacteria which ferment lactose with gas formation within 48 hrs at 37°C . Coliform organisms include diverse microorganisms, the best known of which have been strains of Escherichia coli and Enterobacter aerogenes which are usually, though not always of fecal origin. Coliforms could also be non-fecal types that thrive on organic material of vegetable origin.

The water samples collected from the wells were used to detect the presence of coliforms which are

indirectly indicative of faecal contamination of water bodies. As the coliforms were not detected in any of the water samples it rules out the possibility of faecal contamination. The WHO standards for coliforms prescribe that no E. coli should be present in the 100 ml volume of water samples.

The biochemical oxygen demand (BOD) of a system can be increased by the addition of both organic and some inorganic substances to the environment. All of this organic material eventually reaches the regeneration zone, where it can be broken into its component parts through microbiological action. As there is a large amount of organic matter to be broken down, the microorganisms remove large quantities of dissolved oxygen from system (the BOD increases), (APHA, 1985). The estimates for BOD in the present studies show that the BOD of all the wells at both the sites, except bore wells was more than the maximum limit of 2.0 mg l^{-1} as given in ISI (1983). However, the nearest wells to the dumping grounds at both the sites had more BOD than the others (13 and 15.5 mg l^{-1}). This clearly shows that the nearest water sources are polluted more than others. This is due to increased leaching of organic materials from landfill sites.

The potassium content of well waters ranged from 8.0 to 26.0 and 4.8 to 57.6 mg l^{-1} in Golkonda and

Amberpet (summer) sites. In general the main source of potassium in ground water is silicate minerals, igneous and metamorphic rocks (Karnath, 1987). The results clearly shows that there is an increase in potassium content of well waters of Amberpet and Golkonda landfill sites. The maximum values were observed in the nearest wells at both the sites. The water soluble potassium is getting leached out from the landfill and reaching the ground water contributing the significant increase in total dissolved solids.

The sodium content of well waters ranged from 100 to 450 and 1160 to 1560 mg l^{-1} in Golkonda and Amberpet (summer) respectively. The increase of sodium was more in summer due to evaporation. The nearest wells had more sodium dissolved in their waters than distant bore wells. At Golkonda site, first three wells and at Amberpet four wells in monsoon and all the wells in summer analysed for sodium content than standard limit prescribed by WHO i.e., 200 mg l^{-1} . This clearly shows that ground water near landfill sites are charged with increased sodium content due to leaching from solid waste landfills because of the high solubility of sodium salts and minerals which contributed for total dissolved solids to a greater extent. Sodium levels in ground water vary widely but normally range between 6 and 130 mg l^{-1} .

High concentration of chloride gives an undesirable taste to water. Lockhart et al. (1955) reported that the taste thresholds of chloride ion in water varied from 210 to 310 mg l⁻¹. Chloride is considered to be the most troublesome anion for irrigation in the sense that it is more toxic than sulphates for the plants (Vijayram et al., 1989). The chloride contents of well waters in the present study ranged from 74.0 to 269 and 480 to 935 mg l⁻¹ in Golkonda and Amberpet (summer) sites respectively. The chloride contents at Golkonda and Amberpet (monsoon) well waters except Amberpet (summer) are nearly as per the standard limit prescribed by the ISI (1983), ICMR (1975) and WHO (1984) i.e., 250 mg l⁻¹ for potable water and 600 mg l⁻¹ for irrigation water class E prescribed by ISI (1982).

Similarly, Olaniya and Saxena (1977) reported chloride values from 80-680 mg l⁻¹ in well near an open refuse dump at Jaipur. Beyond prescribed limit, chloride affects taste, becomes more corrosive to supply pipelines and adversely affect palatability. The chloride content of nearby wells increased over bore wells due to seepage of leachate from dumping ground into the groundwater and the chloride content decreased with increase in the distance. Similar results were also reported by Olaniya and Saxena (1977).

The concentration of sulphates in all the well water samples at both the sites were found within the prescribed limit of 400 mg l^{-1} (WHO, 1984), 250 mg l^{-1} (ICMR, 1975) for drinking and 1000 mg l^{-1} (ISI, class E, 1982) for irrigation. But four samples of well waters from Amberpet (Summer) had values higher than the ISI (1983) recommended values for drinking water i.e., 150 mg l^{-1} . It could be noted that the sulphates comparatively have less effect on taste of water than chloride and carbonates. Beyond the prescribed limits, it causes gastro intestinal irritation when magnesium or sodium are present. Similarly Olaniya and Saxena (1977) reported sulphate values of $48\text{-}280 \text{ mg l}^{-1}$ in well waters near an open refuse dumping ground at Jaipur. Nicholson et al. (1983) studied ground water pollution at a landfill site in Ontario, Canada and reported that maximum sulphate was 2000 mg l^{-1} . The sulphate content in well water decreased with increase in the distance from the landfill site. The increase in sulphate content of well waters when compared to bore well waters is due to seepage of leachate from landfill sites to groundwater table.

The phosphate contents of nearest wells were found to be 2.1 to 3.0 mg l^{-1} which were higher than others and decreased as distance increased. While studying the well water characteristics at an open refuse dump at Jaipur, Olaniya and Saxena (1977) reported that

the values of $\text{PO}_4\text{-P}$ ranged from nil to 3.0 mg l^{-1} .

The boron content of all well waters ranged from 0.3 to 2.2 at both the sites and were within the prescribed ISI (1982) Class E limits for irrigation water i.e., 2.0 mg l^{-1} . However, there was an increase in boron content of nearest wells when compared with bore wells, indicating the pollution of ground water due to landfill sites in shallow wells.

The content of bi-carbonates were found to be more than carbonates in all the well waters at both the sites. Bi-carbonates ranged from 84 to 895 mg l^{-1} in all the water samples and increased in concentration in open wells more than in bore well. Nicholson et al. (1983) studied ground water characteristics at a landfill in Ontario, Canada and reported that bi-carbonate content of waters was 1200 mg l^{-1} .

The presence of nitrate-N not only causes cyanosis among infants when present in considerable quantity but also has been reported to cause gastric cancer (Dhanaselvan and Lakshmanaperumal Samy, 1991). The nitrate content was more at Amberpet in summer (13.5 mg l^{-1}). Nitrogen in aquatic system is contributed through organic matter, chemically and waste water discharges and reach ground water through percolation (Peavy et al., 1986). The nitrate values of all the

wells were found within the prescribed limits of ISI (1983) (45 mg l^{-1}), whereas only two wells in Amberpet (summer) had more $\text{NO}_3\text{-N}$ than WHO (1984) prescribed limit of 10 mg l^{-1} . Beyond prescribed limit causes nitrates are reported to be the cause of methaemoglobinemia in infants. The increase in $\text{NO}_3\text{-N}$ content is mainly due to the fact that seepage of leachate after decomposition of solid wastes in the landfill reaches the groundwater. Similarly Olaniya and Saxena (1977) reported $\text{NO}_3\text{-N}$ content of 0.8 to 10 mg l^{-1} while studying the groundwater pollution by open refuse dumps at Jaipur.

The $\text{NH}_4\text{-N}$ content of all the well waters ranged from nil to 0.4 mg l^{-1} . Similarly Olaniya and Saxena (1977) reported $\text{NH}_4\text{-N}$ values ranging from nil to 2.0 mg l^{-1} in groundwater of Jaipur near an open refuse dump. The increase in $\text{NH}_4\text{-N}$ when compared to borewell waters, indicates that nearest water sources get charged with leachate generated by the landfills at both the sites. In general, it decreased with increase in distance. Similar results were reported by Olaniya and Saxena (1977).

The total alkalinity as CaCO_3 content of all the well waters ranged from 156.0 to 1115.0 mg l^{-1} and they are very much above the prescribed limit of ICMR (1975) i.e., 120 mg l^{-1} . Similarly Olaniya and Saxena (1977) reported values ranging from 140 to 1244 mg l^{-1}

in well waters near an open refuse dumps at Jaipur. In all the well waters at both the sites Mo-alkalinity was found to be more than the P-alkalinity due to presence of bi-carbonates. The pH was also in alkaline range.

The values of fluoride in all groundwater samples were within the prescribed limit of ISI-1983 (0.6 to 1.2 mg l^{-1}) and WHO-1984 (1.5 mg l^{-1}). Relatively low level of fluoride are linked with dental caries. At levels of fluoride above 1.5 mg l^{-1} , mottling of teeth and bone fluorosis have been reported (Vijayaram et al., 1989). The fluoride concentration of 0.6 mg l^{-1} or more may lead to dental decay in children. It may be said that different locations in the same area have different concentrations of fluoride. In general, it can be concluded that fluoride concentration in well waters near to the landfill sites were not increased due to seepage of the landfill leachates.

The chemical oxygen demand of well waters ranged from 1.1 to 24.0 mg l^{-1} at both the sites. The highest COD values were found in nearest wells at both the sites indicating contamination of well waters with relatively easily oxidizable organic matter. The leachate generated at landfill site must have percolated through the soil and found its entry into the ground water table. The COD values decreased in the well water as the distance from the refuse dumping grounds

increased. Similarly Olaniya and Saxena (1977) reported COD values of wells from nil to 200 mg l^{-1} while studying ground water pollution by an open refuse dumps at Jaipur (Rajasthan).

Iron is the fourth most abundant element by weight in the earth's crust. It occurs mainly in the divalent and trivalent states in water. The presence of iron in water can be attributed to the dissolution of rocks and minerals, landfill leachates, sewage and industrial effluents. In the present study, the iron content of all the well waters ranged from 100.0 to 1500.0 ug l^{-1} at both the sites. Almost all the well waters contained Fe beyond the limit of 0.3 mg l^{-1} prescribed by ISI (1983), ICMR (1975) and WHO (1984) for drinking water. Beyond this limit, taste and appearance are affected which have adverse effects on domestic uses and water supply structures and promotes activity of iron oxidizing and reducing bacteria. Similarly Olaniya and Saxena (1977) also reported the Fe values ranged from nil to 3000.0 ug l^{-1} or 3.0 mg l^{-1} in well waters near an open refuse dumping ground at Jaipur. In the present study, the increase in Fe content of well waters may be attributed to contamination of ground water with landfill leachate, as there are no industries located nearby at these two landfill sites.

The presence of manganese in natural water occurs in both dissolved and suspended forms. The results of this study revealed that the concentration of manganese in all the waters exceeded the limit of 100 ug l^{-1} prescribed by the ISI (1983), ICMR (1975) and WHO (1984) for drinking water. The manganese in all the well waters ranged from 100.0 to 930.0 ug l^{-1} . Beyond the limit of 100 ug l^{-1} taste and appearance of well waters are affected showing adverse effect on domestic uses and water supply structures.

The zinc content of all the well waters studied showed values within the prescribed limits of 5.0 mg l^{-1} or 5000 ug l^{-1} given by ISI (1983), ICMR (1975) and WHO (1984) for drinking water. It ranged from 20.0 to 580.0 ug l^{-1} in all the wells studied at both the sites. Beyond the prescribed limit zinc dissolved in water can cause astringent taste and an opalescence in waters. From this study, it can be said that Zn concentration is not a cause for alarm as the concentration of dissolved Zn was far below the limit prescribed.

The copper concentration in well waters ranged from nil to 5.0 ug l^{-1} and they were within the prescribed limits of 0.05 mg l^{-1} or 50 ug l^{-1} given in ISI (1983), ICMR (1973) and 1.0 mg l^{-1} by WHO (1984) for drinking waters. Beyond the prescribed limit copper gives astringent taste, discoloration and corrosion of

pipes, fittings and utensils. The results clearly showed that Cu concentration is not increased in well waters near landfill sites.

The lead content of well waters ranged from 6.0 to 34.5 $\mu\text{g l}^{-1}$ at both the sites. In most of the wells, it was within the prescribed limits of 0.1 mg l^{-1} or 100 $\mu\text{g l}^{-1}$ and 0.5 mg l^{-1} given by ISI (1983) and WHO (1984) respectively. Beyond the limit, the water is toxic for human and animal consumption. The source of lead in solid wastes is lead storage batteries for automobiles, the electrodes of a typical battery containing 93 per cent lead dioxide and 7 per cent antimony and other sources of metal products, printing chemicals, pigments etc. All these contribute to lead content in urban solid wastes (Chhatwal, 1989). In the present case, the concentration is very much lower than the limits, hence, it reveals non-toxic character. However, waters from all these wells, except borewells, are not used for drinking at both the disposal sites.

The nickel concentration in well waters ranged from 4.0 to 9.0 $\mu\text{g l}^{-1}$ at both the disposal sites. These low levels indicate non-toxic characters of waters in respect of this element.

The chromium content of all the well waters at both the sites were within the prescribed limit of 0.05 mg l^{-1} or 50 $\mu\text{g l}^{-1}$ as given by ISI (1983) and WHO

(1984) for drinking waters. Beyond this limit, it becomes carcinogenic. In wells it ranged from 1.5 to 10.0 $\mu\text{g l}^{-1}$ indicating non-toxic character of water in respect of this element.

The cobalt content of well waters ranged from 3.6 to 10.0 $\mu\text{g l}^{-1}$ at both the sites. The geochemical behaviour of cobalt is similar to nickel. The permissible limit of cobalt is 1.0 mg l^{-1} or 1000 $\mu\text{g l}^{-1}$ (Rodier, 1975) and, hence, at the concentration detected cobalt can be considered as non-toxic.

Cadmium could not be detected in any of the well water samples at both the landfill sites of Golkonda and Amberpet. The permissible limit prescribed by the ISI (1983) is 0.01 mg l^{-1} and WHO (1984) is 0.005 mg l^{-1} . Beyond this limit, the water becomes toxic.

In normal river and groundwaters, the contents of Cu, Zn, Co, Ni, Cr and Pb are generally less than 10 $\mu\text{g l}^{-1}$.

The present investigation reveals the existence of Fe and Mn in considerable quantity in most of the water samples but all other trace elements were within the standard limits.

Although some trace metals are indispensable for the present needs of life, they may produce serious

problems if they exceed in prescribed limits in long run. Similarly Nicholson et al. (1983) reported that no heavy metals or trace elements accumulated above the maximum limits in drinking water in wells near landfill site in Ontario, Canada.

From the foregoing discussion, it can be concluded that most of the groundwater samples at Golkonda and Amberpet are not suitable for the purpose of drinking and irrigation. The reasons for higher value of physico-chemical parameters may well be ascribed to unscientific disposal of urban solid wastes at landfill sites, where leachate percolates through soil and contaminate the groundwater.

Entry of pollutants into groundwater takes place by percolation from ground surface. From a point source (landfill site) the extent of pollution of groundwater decreases as pollutants move away from the point source until a harmless or very low concentration level is reached. Each constituent of a pollution source have different attenuation rate and each quality component will vary in the distance to be travelled.

Once the groundwater source gets polluted, the effect may persist for decades or even centuries. The reclamation of surface water is easier than reclamation of groundwater, hence, prevention of groundwater pollution due to any cause is very important.

5.5 RESPONSE OF MAIZE TO URBAN SOLID WASTE AND FARM YARD MANURE APPLICATION AND UPTAKE OF MICRONUTRIENTS AND HEAVY METALS

Use of fresh USW as a manure for cultivation of crops is a very common agronomic practice in areas around Hyderabad city. Due to lack of any other better source of organic manure the farmers are resorting to the use of USW for cultivating vegetable crops, sorghum, maize and paddy. Such a practice is also prevalent in other cities in India. It is, therefore, important that the effect of such practice on yields of crops and uptake of micronutrients and heavy metals be evaluated. With this in view, a pot culture experiment was conducted by using different levels of USW application. FYM was also used as source of organic matter for purposes of comparison. The results obtained are discussed here.

5.5.1 Dry matter yield

In general, application of USW and FYM increased the dry matter yield of maize over control with some exceptions. Interestingly, a decrease in dry matter production at 44 t ha⁻¹ level of waste treatment occurred as compared to other treatments. These observations are in agreement with the findings of Mans et al. (1973), who attributed the beneficial effects of

wastes to its plant nutrients and organic matter content. Reduced crop yields have been reported with high levels of organic wastes application by several workers. Shukla et al. (1978) reported that high levels of FYM application reduced maize yield. Similarly, Gupta et al. (1983) also reported that the application of FYM upto 10 t ha^{-1} enhanced dry matter yield of maize while 20 t ha^{-1} depressed the yields. This effect was attributed to the strong complexation reaction between humic acid fraction of organic matter and nutrients and biological immobilization of native soil nitrogen and other macro and micro-nutrients. However, no visible deficiency or phytotoxic symptoms were evident from the present study at higher levels of waste application. As a blanket application of N, P and K was done for all the treatments including control, it has probably masked effect of application of different levels of urban solid wastes and FYM. The main purpose of experiment, however, was to ascertain the impact of waste application on the accumulation of micronutrients and heavy metals in soil and plant.

Several workers studied the usefulness of USW with and without application of N, P and K on dry matter production of crops and concluded that application of N, P and K along with urban solid wastes or farmyard manure gave better yields of crops (Hortanstine and Rothwell, 1972; 1973; King and Morris, 1969; King et al., 1977;

Vimal and Talashilkar, 1984; Gaur, 1979; Bhardwaj and Gaur, 1985). The initial nutrient levels of the soil relate strongly to crop response to waste applications during the first cropping season (Hortenstine and Rothwell, 1982) and subsequent waste addition every year, the response changes and this needs to be investigated in a long term manurial experiment.

✓ This study clearly showed that along with recommended doses of N, P and K the application of wastes upto 33 t ha^{-1} gave better yields than only with fertilizers.

5.5.2 Effect of organic wastes on uptake of micro-nutrients and heavy metals by maize crop

The results (Table ✓ 51) indicated that the uptake of iron by maize decreased at all the levels of waste application. It ranged from 7.8 to $36.78 \text{ mg pot}^{-1}$. This may be due to low availability of iron from wastes applied. This is evident from the relatively availability data on organic wastes and making soil Fe unavailable to the plant. However, the DTPA-extractable soil Fe increased (McCaslin and O'Connor, 1982) after harvest of the maize crop. Similar results were also reported by D'Souza and Ramachandran (1984).

Similarly, Cu uptake was also affected due to organic wastes application. This decrease may be due to

formation of organo-metal complexes with Cu present in the soil with application of organic wastes, as there is a greater affinity of organic matter to copper to form complexes. The Mn uptake increased upto 33 t ha^{-1} waste addition which decreased at 44 t ha^{-1} waste application. The decrease in Mn uptake by the maize plant at higher dose of waste application can be attributed to raise in soil pH due to organic waste addition (Page, 1966) and also may be due to liming effect of organic matter present in wastes (Chu and Wong, 1987). In the long run, this could lead to waste induced manganese deficiency and additionally the Zn added through USW may inhibit Mn uptake (Mass, 1967 and Singh and Steenberg, 1974). However, the contents of Fe, Mn and Cu in plant tissue were above the critical levels.

Urban Solid Waste and FYM application increased plant Zn uptake by maize at all the levels significantly as compared to control and ranged from 1.3 to 2.82 mg pot^{-1} . King et al. (1977) also reported that the application of USW improved Zn status of maize. The reports of D'Souza and Ramachandran (1984), Petruzzelli et al. (1989) and Reddy et al. (1989) also confirm these findings in respect of Zn availability and uptake by plants on the application of USW and FYM to soil.

The data on heavy metal uptake by maize plant (Table 52) revealed that the plant lead and nickel

uptake increased significantly over control and ranged from 42.0 to 913.0 and 3.9 to 89.5 $\mu\text{g pot}^{-1}$ respectively. Due to FYM application also the Pb and Ni uptake increased but was less than USW treatments. The cobalt uptake was also increased significantly and reached a peak of 12.1 $\mu\text{g pot}^{-1}$. There were no significant differences in respect of the uptake of Cd and Cr and in many treatments, the two heavy metals occurred only in traces in maize plants. D'Souza and Ramachandra (1984) also failed to get any significant variation in the uptake of Cd and Cr due to application of USW generated from Bombay city in India.

The absolute quantity of added micronutrients through organic manures may not be quite considerable but the mineralization of the elements from organic combinations or immobilization of the elements from inorganic form to organic forms may be more crucial in determining the rate of uptake of the elements by crops. Among the different heavy metals studied, Pb, Ni and Co uptake was significant, whereas Cd and Cr uptake was negligible. The uptake of heavy metals with FYM was less when compared with USW treatments. This clearly indicates the potential hazard of increased uptake of heavy metals like Zn, Pb, Ni and Co when USW are applied to soil. Contents of these elements in maize though did

not attain or exceed toxic dietary limits, this should, however, be viewed with caution because of the potential health hazard once they reach the food chain. The rate of application of USW should be carefully monitored, regulated and, if necessary, staggered to prevent such health hazards.

As it is evident from the data (Table 53) that addition of organic wastes and FYM significantly decreased Fe content in roots and stems of maize plant and they ranged from 1182.0 to 3667.0 and 52.0 to 330.0 ppm, respectively. The low availability of Fe may be attributed to low availability of Fe from wastes, as we can see from relative availability data and immobilization of native available iron by organic ligands at all the levels of application. This may also be partly due to the increasing availability of copper due to the application of USW and copper is reported to inhibit the uptake of Fe by plant roots (Chapman et al., 1939; Guest and Chapman, 1944 and Hewitt, 1948). In case of FYM application, copper levels were, however, not in excess. Also symptomatically typical deficiency of Fe was not evident in the maize plant at harvest, because the leaf content of iron was above the critical level of 15 ppm.

The Mn content of maize root and stem increased over control whereas in leaf it decreased significantly

with some exceptions and ranged from 5.0 to 115.0 ppm. Three possible reasons could be ascribed for the reduced distribution of Mn in the foliage. Page (1966) reasoned that decreased uptake of Mn by plant foliage may be due to the increase in pH of soil recorded when urban solid wastes were added to soil. In addition, the organic matter contained in USW limit, metal availability and results in lower Mn accumulation in crops (Chu and Wong, 1987). This could lead to induced Mn deficiency in crops. Thirdly zinc also is reported to competitively inhibit Mn uptake by plants (Mass, 1967; Singh and Steenberg, 1974). However, Mn deficiency was not apparent in the maize plant at the time of harvest as the leaf content of Mn was above the critical level of 15 ppm, except in one treatment, when Amberpet, stabilized waste was added at 11.0 t ha^{-1} . In this treatment, the Mn concentration in maize leaf was only 5.0 ppm.

The significant increase of Zn concentration in roots, stem and leaves is due to the increased availability of Zn in USW and FYM amended soil. In the plant parts, the maximum Zn values found in roots, stems and leaves were 133, 35 and 86 ppm, respectively. These results are consistent with the findings of King et al. (1974) and Reddy et al. (1989). The zinc concentration in the plant parts were not in the toxic range.

The Cu concentration of various tissues of maize differed significantly. Relatively low content of Cu in maize tissue could be attributed to strong chelation of Cu by organic matter contained in the USW applied. In some treatments, the Cu content in leaf was below the critical level of 5 ppm at the time of harvest.

In general, copper content found in the maize tissue are within the limits of Cu content normally reported for maize. King and Giordano (1986) and Reddy et al. (1989) also obtained similar results in respect of Cu concentration in different plant parts on the application of organic solid wastes to soil. The lead concentration in root was more than in stem and leaf (Table 54). This suggests that root tissue showed a tendency to accumulate more Pb from waste than either leaf or stem. Relatively low concentration of Pb in maize leaf as compared to root could be attributed to a tendency of maize to retention of Pb in the root cell sap. The increase of Pb in maize plant tissue, except in FYM treatments may be due to Pb supplying capacity of urban wastes as is evident from the data on relative availability of Pb in different treatments receiving USW or FYM. Similar trend was observed with nickel and Co content in the maize plant parts.

However, the contents of heavy metals were not in toxic range. Similar results were also reported by D'Souza and Ramachandran (1984). The Cr and Cd in maize tissue were not in detectable range because of the low DTPA contents of these heavy metals in the USW or FYM.

The contents of heavy metals in maize plant parts were more with USW treatments than with FYM treatments. This indicates FYM safer as far as heavy metal content is concerned and pose no threat to food chain.

5.5.3 Effect of urban solid wastes and FYM on some soil properties

The fig. 13 revealed that the soil pH increased significantly over control after harvest of the maize crop due to addition of organic wastes and ranged from 6.2 to 7.5. This may be due to 'liming effect' of wastes and alkaline nature of USW applied. Such a change in pH was also evident with FYM application but the degree of change was comparatively less. Adachi (1980), Kowaed et al. (1982) and Schossing (1983) also obtained significant increase in soil pH on the application of organic solid wastes.

The electrical conductivity of soil after harvest of maize crop increased due to addition of organic wastes as compared to control (Fig.13). It ranged from 33.0 to 111.0 $\mu S m^{-1}$. Similar results were

reported by Hortenstine and Rothwell (1969); King et al. (1974) and Petruzzelli (1989). However, the EC values were below the critical limit of 500 u S m^{-1} , which is the upper limit for proper seed germination for most of the field crops (Brooks, 1969). But repeated application of USW may be fraught with the danger of development of salinity in the long run. The USW used in the present study had higher levels of DTPA-micronutrients than the soil or the FyM used for pot culture. As a result, the highest DTPA-Fe, Mn, Zn and Cu contents in soils were 14.6, 16.25, 4.4 and 2.4 ppm respectively (Table 55). These contents were far below the levels considered phytotoxic (Viets and Lindsay, 1973; Tiedemann and Lopez, 1982; Petruzzelli et al., 1989). The increase in micronutrients due to addition of organic wastes may not lead to problems of toxicity to plants but may pose a problem due to gradual accumulation in the long run due to repeated application of USW. Eventhough the DTPA-micronutrients in soil increased due to USW application, in general, it need not necessarily lead to increased uptake of these by plants (McCoaslin and O'Connor, 1982). The data (Table 56) obtained show that DTPA-Pb, Ni, Co and Cd contents increased significantly in the soil due to urban solid wastes addition. The maximum values were found to be 6.2, 0.17, 0.15 and 0.09 ppm respectively. These results indicate that the application of USW may pose potential problems because

of gradual build up of heavy metals in soil, if they are used on land repeatedly for cultivation of crops. Even though USW application leads to increased total Cr concentration in soil, the DTPA extractable Cr concentration was, however, low indicating non-extractability of the heavy metal with DTPA. The Cr present in the soil is, thus, in a form not easily extractable by maize plants even at 44 t ha^{-1} of USW addition. Similar results were also reported by Kelling et al. (1977), D'Souza and Ramachandran (1984) and Petruzzelli et al. (1989) with the use of USW on soils. However, it is likely that extractability of metals will vary with source of extractant, waste as well as soil type (Keeney and Walsh, 1975).

In general, higher rates of wastes application lead to reduced extractability of heavy metals and at the low rates of application of USW, the extractable micronutrients were variable in contents, an observation which is also supported by the investigations of Kelling et al. (1977) with USW application to soil.

The data on soil total micronutrients contents in soil are presented in Table 57. Significant increase in total micronutrients in soil was observed after harvest of maize which points out the fact that either USW or FYM can potentially increase the micronutrient content. The total content of micronutrients in wastes

was more than in the soil used for this study. Davies (1980) has also reported that USW were comparatively richer in micronutrient concentration than normal cultivated soils.

Similar to that of total micronutrients, the total heavy metals content also increased significantly due to addition of organic wastes. However, with FYM application, the content of heavy metals did not exhibit any significant change as compared to control at any of the level of application. The increase in total Pb and Cd contents should be considered as alarming as they might enter the food chain eventhough the heavy metal concentrations in the soil after USW application were within the normal ranges as reported by Allaway (1968). But constant use of these wastes over a long period may pose a pollution hazard and this aspect needs further investigations and monitoring on a long term basis.

Chaney (1973) stressed the need for maintaining a low (0.5%) Cd/Zn ratio ($\text{Cd/Zn} \times 100$) in the wastes, which ensures low cadmium content in grains, fruit and root crops relative to the ratio of the wastes. The Cd/Zn ratios of USW and FYM used in the present study ranged from 0.023 to 1.3 per cent indicating that some USW may cause cadmium to accumulate in edible plant parts if used injudiciously as a manure.

An examination of the data (Table 26) showed that the relative availability of micronutrients and heavy metals differed with type of organic wastes. The ranking of elements according to their relative DTPA availability showed that in all cases, with some minor shift in relative position, Cu, Ni, Pb and Zn are most available of the elements studied. Manganese, Co and Cd are moderately available but Cr and Fe have very low availability, but due to organic matter chelation, the Cu uptake was low by the maize crop in the present study. Many of the metals added to soil with the organic wastes would be toxic if completely soluble. However, most of the toxic metals are held in forms that are relatively immobile and unavailable to plants. The extractable amounts are rather small with respect to the total content of micronutrients and heavy metals in organic wastes.

The present study has shown that USW generated in Hyderabad city can be used to increase the fertility and productivity of the sandy soils which are poor in fertility status, along with chemical fertilizers. The effect is probably due to increased addition of organic matter and supply of micronutrients through USW addition. However, the increased level of micronutrients and heavy metals in soil after harvest brought about by application of the wastes clearly caused an elevation of some micronutrients and heavy metal contents in maize

tissue. Toxic effects were evident at higher rates of addition of USW (44 t ha^{-1}) which caused a depression in the yields of maize. This depression in yield cannot be ascribed to a direct effect of elevated heavy metal content in the soil. The yield depression could also be due to imbalance of nutrients, immobilization of major and micronutrients and changes in gas phase in the plant rhizosphere. However, urban solid wastes can be valuable soil amendments if used properly. The combination of high pH and organic matter content of urban solid waste provides a promising means of increasing crop yields even upto 33.0 t ha^{-1} rate of application. Indiscriminate application in excess of 33 t ha^{-1} over prolonged periods may cause soil pollution and phytotoxic effects due to heavy metal build up and other causes. Petruzzeli et al. (1989) reported that the maximum rate of addition of urban refuse compost to soils has been regulated by legislation in Italy and should not exceed $30 \text{ t ha}^{-1} \text{ year}^{-1}$. A careful monitoring of soil and plant for ascertaining the toxic effects is essential to prevent the potential hazards associated with the application of USW to agricultural land. Even at 33.0 t ha^{-1} application every year the bio availability of trace metals may differ because cumulative effect of these trace metals changes after each waste application. Therefore, frequent soil and plant health monitoring is needed to overcome such

problems. This is possible only when the users are aware of the problems associated with the urban solid wastes in agriculture and calls for educating the user farmers on the salient features and problems associated with application of USW to land for the cultivation of food and fodder crops.

5.6 EFFECT OF LAND APPLICATION OF RAW URBAN SOLID WASTES GENERATED IN HYDERABAD CITY ON SOIL PROPERTIES AND UPTAKE OF MICRONUTRIENTS AND HEAVY METALS BY SOME PLANT SPECIES

A preliminary survey was conducted to identify the locations where farmers are using urban solid wastes directly as a source of manure for cultivating crops. Soils and plant samples obtained from these locations were analysed and results presented in previous pages are discussed in the following paragraphs.

5.6.1 Effect on soil properties

Only approximate estimates could be made with regard to the rate of application of fresh USW used by farmers as this was ascertained by personally interviewing the farmers. The rate of addition of fresh urban solid wastes ranged from 80 to 100 t ha⁻¹ annually or in alternate years.

The sand content decreased and silt and clay contents increased upto a depth of 30 cm in soils

treated with urban solid wastes as compared to control soil. This is mainly due to the fact that the Hyderabad urban solid wastes contained considerable quantity of fine earth fraction, which contributes clay and silt to the soil, when applied. This change was noticed upto 30 cm depth of the soil. This may be due to constant ploughing every year after application of wastes which brought change in particle size distribution. Consequently soil texture is also changed and ranged from sandy clay loam to loamy sands.

The soil pH at the sites increased from 6.05 (control) to 8.52 (site 6) due to application of USW over the years.

The alkaline nature of wastes are responsible for such increase in soil pH. Kowaed et al. (1982) reported that the applications of 40, 80 or 120 t ha⁻¹ refuse compost over a two year period increased the soil pH from 5.1 to 5.9, 6.2 and 6.5 respectively. Similarly Otsuka and Adachi (1980) and Schossing (1983) also reported in increasing soil pH due to application of refuse. Petruzzelli et al. (1989) studied four year compost treated soil and reported that soil pH was increased by 0.50 pH units. Relatively, the increase in soil pH was more in the present study because the farmers have been using USW for a long period of time.

The EC of soils of all the sites increased from 0.04 (control) to 2.5 d S m^{-1} (site 4). The increase in EC was also observed to a depth of 30 cm as compared to control. Hortenstine and Rothwell (1969) and King et al. (1974) reported that compost applications increased the soluble salts in the soil. Petruzzelli et al. (1989) studied four year compost treated soil and reported that the electrical conductivity increased from 0.07 S m^{-1} to 0.11 S m^{-1} following the treatment with applicatio of urban waste compost.

The CEC values of soils showed a wide variation ranging from 6.85 (control) to $33.0 \text{ Cmol (P+) kg}^{-1}$ soil. The increase in CEC in these waste treated soils could be ascribed to the increase in clay and organic matter contents as compared to control. Murillo et al. (1989) reported that successive application of city waste compost increased soil CEC in the top 0-10 cm soil and at a depth of 12-22 cm following applications of 150 and 400 t compost ha^{-1} .

The present base saturation varied from 62.80 to 99.64. The dominant cation on the exchange complex of soils under investigation was Ca^{++} followed by Mg^{++} , Na^{+} and K^{+} . The exchangeable cations increased over control. The exchangeable sodium content ranged from 0.02 to $3.36 \text{ Cmol (P+) kg}^{-1}$ soil. The ESP of soils ranged from 0.18 to 20.66. In some soils, the ESP was

greater than 15 per cent, hence, were alkali in nature. The addition of USW indiscriminately over a long period of time made some soils alkaline. Similarly, Murillo et al. (1989) reported that successive application of city waste compost on soil increased soil sodium content and occasionally reached levels close to three per cent which could cause problems and they suggested that compost quality control would be an important factor.

The organic carbon content of the soil samples ranged from 0.42 to 1.90 per cent. Webber (1978), Sotomayor (1979), Otsuka and Adachi (1980) reported increase in soil OC content due to refuse compost application. Kowaed et al. (1982) reported that the applications of 40, 80 or 120 t ha⁻¹ refuse compost over a two year period increased the soil OC content from 1.25 to 1.59 per cent. Petruzzelli et al. (1989) studied four year compost treated soil and reported that soil OC content increased from 0.09 to 0.17 per cent.

The concentration of major nutrients N, P and K in available forms increased due to application of fresh urban wastes as compared to control. The available nitrogen ranged from 118.7 to 277.7 kg N ha⁻¹. The available P₂O₅ content ranged from 16.1 to 72.8 kg P₂O₅ ha⁻¹, whereas available K₂O content ranged from 114.2 to 896.0 kg K₂O ha⁻¹. Hortenstine and Rothwell (1969), Sotomayor (1979) and Kowaed et al. (1982) reported that

application of refuse composts increased the availability of N, P and K contents of soils. Schossing (1983) reported that the refuse compost application at 156.0 or 311.0 t ha⁻¹ to sandy soil increased N, K₂O and P₂O₅. Murillo et al. (1989) reported that successive applications of city waste compost to soil increased N and P in the top soil following applications of 150 and 400 t compost ha⁻¹.

The water soluble ions like K⁺, Na⁺, SO₄⁼ and Cl⁻ were several hundred times as compared to control. This is also evident from the changes in EC values. For preventing salinity problems from organic waste application, the following precautions should be taken:

- * Soluble salt content of wastes should be determined before applying wastes on land.
- * Soil characteristics need to be determined before and after each application of wastes.
- * The amounts of leaching water required to maintain a suitable EC level in the soil to be determined.

The total iron content of soils ranged from 2720.0 to 14800.0 ppm and exhibited a decrease as compared to control. This is due to the fact that wastes contained less total iron than the control soil and the iron content decreased due to the dilution

effect. Consequent to repeated application of wastes on soil the total micronutrients Mn, Zn and Cu increased as compared to control because the total content of these nutrients in wastes is higher than in soils. The total zinc content ranged from 12.1 to 178.0 ppm, Manganese ranged from 90.0 to 470.0 ppm and copper ranged from 4.1 to 73.3 ppm. Davies (1980) analysed garden soils contaminated with urban solid waste and reported that the soil contained 778 ppm Zn and 684 ppm Cu.

The potential, phytotoxicity for Zn and Cu exists not only in total content of an element but also the chemical forms in which the elements occur. Zinc may be present as sulfide, hydroxide, carbonate and Zn metal or as a constituent of galvanized iron and steel, it can be in rubber or within coloured glass. Each of these can be present in different proportions in urban solid wastes (Eaton et al., 1975).

The total heavy metal content in soils increased as compared to control with some exceptions. Lead content varied from 4.3 to 172.0, nickel 0.9 to 12.6, cobalt 1.0 to 9.0, cadmium 0.3 to 0.9 and chromium 5.4 to 50.0 ppm. Spittler and Feeder (1979) reported that soil from urban gardens contained 800 ppm lead. Haon (1981) reported biennial applications of compost upto 40 t ha^{-1} between 1948 and 1978 resulted in large increase in micro element contents in soils. Schossing

(1983) reported that refuse compost applied at 156.0 or 311.0 t ha⁻¹ to 35 cm depth to poor sandy soil increased Ni, Cr, Cd and Pb contents. Morillo et al. (1989) presented data which indicated that successive application of city waste compost on soil increased total heavy metal content in the top 0-10 cm soil and at a depth of 12-22 cm following applications of 150 and 400 t compost ha⁻¹.

The DT PA-micronutrients and heavy metals increased several folds as compared to control. The data are presented in Tables 66 and 67. The increase was mainly due to the contribution of microelements and heavy metals from USW. The build up of some DTPA-trace metals is so high that they may cause phytotoxicity in the long run. The accumulation of phytotoxic levels of microelements in the soil from repeated applications of metal rich wastes is of serious concern threatening the practice of ultimate disposal of urban wastes on agricultural land. Because removal of most of these microelements by cropping would be slow, their accumulation presents a long term potential for phyhtotoxicity. Takkar and Mann (1978) described zinc toxicity symptoms in wheat and maize. Further they reported that 7.00 ppm DTPA extractable soil Zn was toxic to wheat and 11.0 ppm to maize. Phytotoxicity of Cu will ordinarily inhibit

plant growth before Cu contents in phytotoxic range would be found in plants (NAS, 1974).

Giusquiani et al. (1988) studied the influence of urban waste compost on soil properties and concluded that only Zn increased remarkably and could cause problems of phytotoxicity. Petruzzelli et al. (1989) studied four year compost treated soil for heavy metal extractability and reported that DTPA-microelements like Cu increased from 16.0 to 25.4, Zn 21.1 to 37.4, Pb 9.2 to 16.1, Cr 1.3 to 1.9 and Ni 3.8 to 6.7 ppm.

The results obtained in this study agrees with the findings of previous workers (Banin et al., 1981; Emmerich et al., 1982).

The ranking of elements (Table 68) according to their relative DTPA availability in the soil shows that in all the cases, with some minor shift in relative position, Cu, Cd and Pb are most available of the elements studied. Elements like Ni, Zn, Mn and Co are moderately available but Cr and Fe have very low availability. Similar results were also reported by Williams et al. (1980).

It can be concluded from the present study that soils may get contaminated with microelements from additions of USW. Total and DTPA metal contents increased in 0-15 and 15-30 cm soil depths. Some of the metals added

with the USW are already present in soil in amounts that would be toxic if are completely soluble.

5.6.2 Distribution of micronutrients and heavy metals in plant parts

The effect of land disposal of urban solid wastes on levels of micro-elements in the foliage and the edible plant parts is important because this is the first stage of the entry of such constituents which may become toxic into the food chain of urban solid wastes when applied in land simultaneously add several metals and microelements. This coupled with plant differences, clouds any ordered picture of plant uptake of waste borne microelements.

From the present investigations the following pattern of uptake of microelements and heavy metals were evident.

The total iron content of plants varied depending on plant species and plant parts studied. In roots, the content of iron is more than in plant tops, with some exceptions. In general, no iron deficient or toxic content was recorded in the plant species studied. The iron content of all parts were in normal range and it is considered as a non-pollutant. Whether organic wastes can be safely used to correct Fe deficiency remains uncertain. The wastes vary widely in Fe

content and chemical form in which the metal occurs. Other heavy metals (Zn, Cu etc.) contained in the wastes if added in high amounts may induce Fe, deficiency in long run. Copper or Ni inhibition of translocation of Fe from roots to tops has been demonstrated. The chlorosis caused by Cu or Ni can be alleviated by Fe sprays, (Hewitt, 1948). The relative availability of iron from wastes is very low as discussed in previous pages. King et al. (1977) stated that there was no effect of refuse treatments on iron content of stover at 188 and 376 t ha⁻¹ refuse treatments.

The manganese content of most of the plant tops are within the range of 15-100 ppm reported by Bowen (1966) and Allaway (1968) for agricultural crops. But few plants like paddy, Hibiscus sp. and beet root shoots had more than 100 ppm Mn but were below levels toxic to the crops or to animals that might consume the crops. The Mn contents of the waste treated soil lead to toxicity problems in acid soils (Cottrell, 1975). D'Souza and Ramachandran (1984) reported that the Mn contents in maize shoots were significantly reduced in oxisol with the addition of compost but not in the Vertisol. The manganese content of plants studied neither reached deficiency nor toxicity range, but long term monitoring is necessary as bioavailability of Mn is prone to change with addition of USW continuously on

land. From the current studies, Mn content in plants on application of USW can be considered as non-polluting.

The zinc concentration varied depending on plant species and plant parts studied. The zinc content of all the plant tops are within the range of 15-200 ppm observed by Bowen (1966) and Allaway (1968) for agricultural crop plants. But some of the species (paddy, chillies, jowar, brinjal, bottlegourd and bhendi) more than 50 ppm Zn in shoots, a content above which pollution problems may be encountered as reported by Etherington (1982). King et al. (1974) reported that application of pulverized municipal refuse increased Zn concentration in rye and corn plants but were below levels toxic to the crops or to animals that might consume the crops. King et al. (1977) concluded that the increased availability of zinc with treatments containing refuse was consistent in a greenhouse experiment. Nogales et al. (1985) reported that application of compost increased zinc concentration and zinc uptake by rye grass. Petruzzelli et al. (1989) reported that repeated refuse compost additions at the maximum rate allowed by Italian legislation ($30 \text{ t ha}^{-1} \text{ year}^{-1}$) increased zinc concentration of maize roots from 34.6 to 146.8 ppm and in grains from 26.8 to 35.8 ppm. Reddy et al. (1989) reported that addition of sewage sludge increased zinc contents in corn leaf and stem, and as the rate of sludge increased the Zn in grain was not

affected. It is evident from the total soil zinc and DTPA-extractable zinc of soils studied that zinc content in plants may cause pollution problem in the long run at these locations.

The concentration of copper in the plant shoots studied was more than 4-15 ppm range provided by Bowen (1966) and Allaway (1968) for normal agricultural plants. The Cu content in shoots of most of the plant species was in excess of 4-5 ppm proposed by Etherington (1982), above which pollution problems may arise. King et al. (1974) reported that by application of pulverized municipal refuse, copper content in rye and corn plants were increased though they were below levels toxic to the crops. Keeling et al. (1977) reported that the addition of sludge increased the concentration of Cu in the vegetative tissue of corn. Cottrell (1975) stated that some beneficial fertilizer effect was obtained from Cu in the refuse material. Petruzzelli et al. (1989) reported results of a four year field experiment on the influence of repeated refuse compost addition on transfer of microelements from the soil to corn crop. The results showed that Cu increased in grains from 2.4 to 4.2 ppm. Reddy et al. (1989) reported increase in copper content of corn leaf more than in stem and grain as the rate of sludge addition increased. Copper contents in crops grown on lands treated with municipal

solid wastes have not been elevated to levels indicative of hazard from Cu toxicity to consumers of the plants. Similar results were also reported by Peterson et al. (1971). Phytotoxicity of Cu will ordinarily inhibit plant growth before Cu contents in this range would be found in plants (NAS, 1974).

Application of Cu through organic wastes may help to prevent Cu deficiency in plants and possibly in animals but may remain as a not so well defined method for correction of deficiencies of Cu or any other micro-nutrient because of the highly variable nature of USW.

In some soils excessive levels of copper may be present without adversely affecting plant growth (Dykeman and de'Sousa , 1966). The lack of toxic effect in such cases is due to the interaction of copper with soil organic matter to immobilize the excessive copper due to strong binding action and chelation.

In the present investigation, the copper levels in plants increased more than 5 ppm, a fact, which has to be viewed seriously as this might have the potential to cause toxicity in the long run due to continuous and uncontrolled application of USW on land. The Cu content in such situations need continuous and careful monitoring.

The lead content of roots was more than plant tops. By and large the contents of lead in plant tops were within the range of 0.1 to 10 ppm as suggested by Bowen (1966) and Allaway (1968). But some species had more than 15 ppm in shoots (chillies, bottleguord, raddish) a higher content which Etherington (1982) considered as causative of pollution hazards in agricultural crops. The content of more than 15 ppm Pb in shoots can be implicated to be due to addition of USW to land in these as the USW had a significantly high level of total Pb ranging from 88-96 ppm. However, it is also clear from these studies that much of the lead absorbed by the plant is retained in the roots and the movement upwards is restricted.

King et al. (1974) reported that the concentration of Pb in rye and corn plants increased due to application pulverised municipal refuse. Pietz et al. (1978) reported that corn grains contained < 0.2 ppm Pb. In another study, Spitter and Feder (1979) studied growth and Pb uptake of plants in garden soils containing a range of Pb levels (100-2000 ppm). The uptake of Pb increased as soil lead increased although uptake varied with the plant species (fruit crops, root crops and leafy vegetables).

In the present study also, significant differences in lead uptake and distribution in plant parts was evident.

D'Souse and Ramachandran (1984) reported that application of Bombay city compost increased uptake of Pb in corn plant in Oxisol but not in Vertisol.

The nickel contents of most of the shoots are more than 1.0 ppm, the limit suggested by Bowen (1966) and Allaway (1968) for agricultural crops. However, in a few plant species the concentration exceeded 5.0 (bottleguord and bhendi). Etherington (1982) has proposed that Ni concentration in excess of 5 ppm may pose pollution hazards.

The nickel uptake and concentration in plant foliage differed markedly between species. Hutchinson and Whitby (1974) also reported such variation in plant uptake of Ni and other heavy metals. Generally, additions of nickel from USW, eventhough much of it is organically found to increase nickel content in both root and shoot in a wide range of crop plants studied. Similar results were also reported by Page (1974) and Soon et al. (1980).

D'Souza and Ramachandran (1984) reported that the application of Bombay city compost increased concentrations of nickel in maize in Oxisol but not in Vertisol. In the present study, while both plant foliage and root levels of nickel are generally lower than those

in soils, marked exceptions occurred under polluted soil conditions with accumulator species (chillies, bottleguord, tomato and brinjal). Similar results were also reported by Brooks and Crooks (1980). Keeny and Walsh (1975) obtained values of 0.9 - 2.5 ppm Ni for rye, sorghum and maize grown on agricultural soils not treated with organic solid wastes.

Monitoring of Ni levels in USW amended soils and crops is desirable for safe utilization of USW as a source of manure to improve soil fertility and productivity.

The cobalt concentration of plant shoots studied were below 1.0 ppm. The normal concentration of cobalt in agricultural crops is 0.05 - 0.5 (Bowen, 1966; Alloway, 1968).

In the present investigation, it was evident that in most plant species studied, roots accumulated more cobalt than shoots and edible parts. The accumulation of cobalt varied from species to species. Similar results were also reported by Lyon et al. (1971).

It can be concluded that the plant species studied contained acceptable content of cobalt in shoots and edible parts and pose no pollution threat to animals or man when they are consumed.

The chromium concentration in the shoots of plant species studied are below 1.0 ppm and within the normal range (0.2 - 1.0 ppm) as suggested by Bowen (1966) and Allaway (1968). But some species (chillies and brinjal) accumulated more chromium i.e., > 0.5 ppm beyond which pollution problems may be encountered. The limit of 0.5 ppm Cr has been suggested by Etherington (1982).

The edible portions of the plant species studied contained least chromium content and, therefore, do not pose any serious pollution problem when these are consumed by animals or by man. Roots accumulated more chromium than the above ground parts. This needs to be monitored carefully when root crops are cultivated on USW treated soils.

In view of the limited possibility for hexavalent Cr to be present in USW, it appears that Cr in these USW poses no hazard to food chain.

In general, shoots contained less than 1.0 ppm Cr (dw) although differences among species have been noticed. The fruits and seed contained less chromium. Similar results were reported by Cary et al. (1977).

Kelling et al. (1977) reported that the addition of sludge did not accumulate Cr in the leaf tissue or in corn grain and further they stated that

DTPA-Cr content did not increase in soil with sludge treatments.

In another study, Pietz et al. (1978) reported that Cr concentration in corn grain was < 0.2 ppm. Similarly D'Souza and Ramachandran (1984) found no change in uptake of Cr by maize with the addition of Bombay city compost to Oxisol or Vertisol.

Chromium may enter USW as chromate from the tanneryeffluents but is apparently reduced to the chromic form (Baetjer, 1974).

It can be concluded from results obtained in the present study that chromium present in the USW poses no toxic pollution problem in the food chain.

The cadmium contents in plant shoots were less than 1.0 ppm. It is within the range of 0.2 to 0.8 ppm as suggested by Bowen (1966) and Allaway (1968) for agricultural crops. The cadmium concentration in edible parts like fruits and seeds ranged from traces to 0.1 ppm. According to Etherington (1982), the concentration of Cd above 0.5 ppm poses pollution hazard. But in the present investigation, cadmium present in the USW treated soils posed no threat to food chain as the contents were lower than 0.5 ppm. However, increase in contents of Cd in roots was evident.

King et al. (1977) reported that cadmium concentration in the maize stover exceeded the safe level of 0.5 ppm for food stuffs when refuse was applied at 376 t ha^{-1} .

Pietz et al. (1978) determined cadmium content of corn grain and reported that it is $< 0.2 \text{ ppm}$. Petruzzelli et al. (1989) reported that the cadmium in corn plants increased particularly in roots from 0.22 to 1.31 ppm. Similar increase was also observed in the present investigation.

Current background levels of Cd are above 0.05 to 0.40 ppm in human diets and the average daily human intake of Cd is probably 40 to 150 ug day^{-1} .

The content of Cd in the edible seeds or fruits is lower than in vegetables (paddy, bhendi and jowar). Similar results were also reported by Chaney (1973).

Procedures for minimizing hazards from Cd have been described by Chaney (1973). Adjustment of Cd/Zn ratios in wastes to keep the level of Cd at less than 0.5 per cent of the Zn, selection of finer textured neutral or alkaline soils as disposal sites, regulation of annual and total application rates and cropping the disposal site to corn for grain are measures that were proposed to help not only to minimize the hazard to food

chains from Cd contained in USW or sludges but also for other heavy metals like Zn, Cu, Pb and Ni.

It can be concluded from the present investigation that Fe, Mn, Cr, Cd and Co not posed any pollution problem in the food chain whereas elevated levels of Zn, Cu, Pb and Ni was observed in the same plant species studied and may pose hazard for food chain in the long run.

The analysis of total heavy metals provides information on the metal load of a polluted soil and helps in assessment of the degree of soil pollution. On the other hand, the DTPA-soil micronutrients and heavy metals reflect the liable metal load of a soil through additions of organic wastes. Increase in DTPA-extractable metals, however, does not mean increase in plant available metal or increased plant uptake (O'Connor, 1988).

Plant analysis gives an indication of the available metals in soils as well as defining the plants own metal load, which is important when the plant is consumed as human food or animal feed.

A major difficulty in predicting potential hazards associated with land disposal of organic solid waste is the inherent variability in the composition of wastes. Nearly every metropolis has industries that

dump their wastes into the normal solid waste disposal channel. The solid waste refuse is therefore extremely heterogenous and the manures obtained from such wastes can also be expected to vary widely in their composition.

It should be ensured that the apparent economic saving for farmers gained by land application of wastes does not become an environmental hazard or cause fertility problem for the future most of the potential problems associated with USW application on land like development of salinity, alkalinity and excessive micro-elements load can be avoided by judicious management through proper selection of wastes, soils and crops and proper reliance on soil and plant testing.

Problems of solid waste collection, handling, transportation and disposal have been highlighted to such an extent in the press (please see clippings of press reports in Appendix I) that Hyderabad has been given the dubious distinction of being called the "Garbage City". The extreme diversity in the characteristics of USW generated in Hyderabad makes it impossible to suggest any one treatment procedure for its safe and useful disposal. However, considering several options available, disposal by landfill is of course, most economical. But if sanitary precautions are not observed while choosing a landfill site, the conse-

quences can be very serious in terms of damage which can be caused by the disposal of USW. As is evident from the study leaching of soluble constituents should be prevented as such a measure only will check pollution of soil and water resources. Land application of fresh USW is no doubt an attractive alternative but this again fraught with some serious consequences as is evident from the present investigations. The soils tend to become saline or even alkali and the load of several heavy metals and other micro-elements in soil increase leading to a situation where pollution abatement measures may become necessary.

Pot culture studies have provided information on the limit to which fresh USW can be applied to land without encountering problems of pollution. The reasonable limit appears to be around 20 to 30 t ha⁻¹ annually but this aspect needs further scrutiny. There is, perhaps, a need for limiting such application of USW on land through proper legislation. Urban solid wastes are no doubt very useful as a resource which can be exploited to advantage if handled and used properly. The present studies have, perhaps, succeeded in assessing the impact of USW disposal on land on pollution of soil and water resources and attempted to provide some alternatives on how best they can be disposed through land application.

The results of the present investigations cannot claim to have answered all vital issues involving disposal of urban solid wastes on land. The work has at best served the purpose of highlighting for the first time the impact of urban solid waste disposal on soil characteristics, ground and surface water quality. The efforts have also provided information on the characteristics of solid wastes and the effect of application of such wastes on plant growth and uptake of nutrients, micro-elements and heavy metals. It has, however, succeeded in providing several leads for further research. The immediate need is to establish a network of research effort to closely monitor the generation, availability and characteristics of solid organic wastes of large and small urban communities, municipalities and agro-based industries. The problem of collection and transportation are different from that their ultimate disposal and sanitary engineers are grappling with such situations. Disposal options for organic solid wastes are limited particularly in developing countries and are restricted to sanitary landfill, composting for land application and bio-conversion for obtaining energy. Among these, the first two are attractive as they are both economical and complete in the sense that all types of wastes can be disposed off. There are some nagging problems of pollution identified from the present investigations as also from the studies of other researchers,

related to the disposal of urban solid wastes on land. It is necessary to pinpoint which of the components in the urban solid wastes are responsible for causing such pollution. This calls for further research.

- * No proper established criteria are available for recommending the optimum loading of soils to receive urban solid wastes as a source of organic matter and nutrient to soil. Among the different countries, Italy has established laws restricting the load to 30 t ha^{-1} annually. To achieve at such a limit of loading, information on waste and soil characteristics, and climatic variations are needed. Such studies are, therefore, needed in different locations where disposal of urban solid wastes poses a problem.
- * One of the problems associated with urban solid waste disposal on land for the cultivation of crops is the build up of soluble salts and heavy metal contents. Ways to mitigate this situation needs to be worked out.
- * It is evident from the literature that the 'stabilization' period of landfills in India are not known. There is a need to study on these lines.

- * Reactions of organic constituents of USW or their microbial breakdown products with metals need to be studied more elaborately.
- * Development of some guidelines for USW disposal in relation to toxic heavy metals on agricultural land is essential before promoting its utilization in agriculture.
- * The information on relationship between the concentrations of metals in soil and uptake by plants and availability of metals in polluted soils with time and significance of the critical concentration of heavy metals in food plants in relation to suggested dietary limits is not available in India.
- * A new approach to guidelines or codes of practice based on the level found in the polluted soil rather than on additions of particular pollutants may also be desirable in that it would look at all forms of pollution which might affect crop growth or composition.
- * Studies on waste, soil and crop management practices and their role in minimizing the pollution of environment are needed

particularly when there is an attractive option available to use USW as source of nutrients and carbon for improving soil fertility in integrated nutrient management systems for achieving sustainability in agriculture.

- * Biological pollution of soils in relation to land disposal of USW needs to be investigated as these wastes under some situations may carry heavy load of pathogenic organisms which can cause diseases to man and animals.

Out of operational expediency it is very common to observe in many urban and semi-urban areas that the urban solid wastes are dumped to reclaim abandoned wells, tanks, low lying areas for reclaiming land. Such reclaimed land is being utilized for establishing housing colonies and industries. The findings of the present study clearly establishes the fact that the soil and groundwater pollution is imminent due to the practice of disposal of large quantities of USW. This practice therefore needs to be discouraged forthwith because once the soil profile gets polluted with pollutants like heavy metals and salts it serves as a store house for polluting the ground water in such areas where land has been reclaimed by using USW.

Hopefully, with proper management, USW can join the select band of organic farm manures and crop residues and bio-fertilizers as an important resource for improving fertility of crop lands.

SUMMARY

CHAPTER VI

SUMMARY

Solid waste generation by a community is linked directly to the standard of living of its citizens. Waste handling and disposal in small and medium urban communities was not a serious problem three decades back. But at present due to increased urbanization and change in life style of urban population collection, transport and disposal of urban solid wastes and liquid wastes is posing a challenge to the administrators and technocrats faced with challenges of improving the quality of life of citizens in small and large urban communities. Eventhough landfill is the most common method employed for the disposal of urban solid wastes, because of the relative ease which the method could be adopted, the urban administration is compelled to look for alternative methods of waste disposal involving recovery of nutrients or energy or both contained in the wastes. This is largely because of the problems involved in transporting wastes to long distances for ultimate disposal as landfill and also because of the scarcity of land for such disposal in the vicinity of urban areas in India as well as in other countries. Some cities in India viz., Bangalore, Delhi, Kanpur and Ahmedabad have been experimenting with the idea of composting the urban solid wastes for obtaining a manure

for land application. In atleast one city viz., Delhi attempts are on to recover the energy contained in the wastes by compacting and burning. In Hyderabad the solid wastes generated in the urban area of the city are disposed off either as landfill in three major landfill sites viz., Amberpet, Golkonda and Autonagar or the fresh wastes are also used by the farmers for direct application to land. One of the three landfill sites, which is the oldest was in use for the past three decades. This is located in the midst of the fast expanding city and, therefore, presently remains abandoned because of lack of space and overload of wastes.

To study the impact of disposal of USW either as landfill or as fresh organic matter directly applied to land, on soil characteristics the present studies were conducted as detailed before. The landfill sites in the city cover a large and expansive area exceeding 10-20 ha each approximately and have received thousands of tonnes of wastes over the decades. To assess the impact of such huge solid waste overloads on soil characteristics (at Amberpet landfill site) and ground and surface water quality, studies were conducted at the Amberpet and Golkonda landfill sites.

Inspite of being labelled as a potential pollution causing material, from the point of view of an

agronomist, USW can be considered as an important resource having the capability to supply organic carbon and several major and micronutrients to soils which usually are low or marginal in their fertility status. To evaluate the manurial value and the concomitant pollution hazards, if any, of urban solid wastes when used as an organic manure, pot culture studies were conducted with different rates of applications of USW. FYM was used as experimental check in these studied.

The results of these investigations are summerised as follows :

The physical and chemical characteristics of urban solid wastes generated in Hyderabad were catalogued. The wastes were highly heterogenous and were in general, poor in decomposable organic matter which might make the wastes unsuitable for composting unless steps are initiated to collect wastes of different types like household garbage, sweepings, market wastes and industrial wastes separately. However the USW disposed off at Golkonda landfill site analysed for higher organic matter which makes it suitable for composting. The contents of soil, dust and gravel were more in the wastes with lesser load of plastics, paper, metals and rubber when compared with the reported characteristics of solid wastes generated in developed countries. This is primarily because of the salvaging of paper,

plastics, rags, metals and rubber from the wastes from street bins and landfill sites.

The USW were alkaline in nature with their pH ranging from 7.7 to 9.6 and the organic carbon content varied from 3.4 to 6.3 per cent. The COD ranged from 89 to 168 mg g⁻¹ with the stabilized wastes (wastes which have undergone decomposition at Amberpet landfill site) recording lower COD. The wastes contained soluble salts, heavy metals and microelements in varying proportions. The electrical conductivity of the wastes was high varying from 130 to 538 $\mu\text{S m}^{-1}$ and from 0.97 to 4.48 d S m⁻¹ in 1 : 50 and 1 : 2 waste to water ratio, respectively. The wastes were calcareous in nature, and the free CaCO₃ content ranged from 5.0 to 7.7 per cent. The wastes possessed cation exchange capacity (CEC) of 50 to 151.0 C mol (P+) kg⁻¹ waste. analysed also for varying contents of major nutrients (N, P and K), secondary nutrients (Ca, Mg and SO₄⁼), micronutrients (Fe, Cu, Mn and Zn) and heavy metals (Pb, Ni, Co, Cr and Cd). The total micronutrient and heavy metal contents followed the decreasing order : Fe > Mn > Zn > Pb > Cu > Cr > Ni > Co > Cd. The extractable (DTPA) micronutrient and heavy metal contents in the wastes followed the decreasing order Fe > Mn > Zn > Cu > Pb > Ni > Co > Cr > Cd. The relative availability of the micronutrients and heavy metals followed in general the order : Cu > Ni > Pb > Zn > Cd > Mn > Co > Cr > Fe.

The Cd/Zn ratio of the wastes ranged from 0.42 to 1.7 which in some cases exceeded the limit of < 0.5 proposed by Chaney (1973) for preventing cadmium toxicity in the eco-systems.

The impact of USW disposal on soil characteristics was investigated by obtaining four profile samples from Amberpet landfill site. The soil profile characteristics were altered to a great extent due to the influence of USW accumulating on the soil surface. The process of mechanical eluviation from the waste overlay and subsequent deposition in the soil profile brought about an increase in silt and clay content of the soil at varying depths.

The pH turned slightly neutral to highly alkaline in some soil depths with the EC also exhibiting substantial increase. The content of water soluble salts and exchangeable Na and K also increased enormously in the soil profile at different depths. The dominant cations on the exchange complex in soil profiles 1 to 4 affected by USW was Ca^{++} , Mg^{++} , K^+ and Na^+ , whereas in runoff affected soil profiles A and B the dominant cations were Na^+ , Ca^{++} , Mg^{++} and K^+ . In soil profile A, Na^+ was dominant and replaced much of the Ca^{++} and Mg^{++} at 150-210 cm depths. The ESP varied from 0.27 incontrol to 70.6. In the soil profiles under the waste dumps accumulation of soluble salts from USW

was more than the movement and accumulation of micronutrients and heavy metals. The concentration of the leached constituents from the USW overlay into soil profile appeared to be related to the solubility of the constituent in water and organic matter and clay contents of the different layers of the soil profile.

A bioassay procedure developed to find out the accumulation of plant growth affecting constituents in the soil profile clearly indicated that when Italian millet was sown in soils obtained from different depths of soil profiles, the seeds failed to germinate and grow in some soil samples which was due to high EC and ESP.

The quality of runoff and ground water due to disposal of USW as landfill was investigated. The runoff water at Amberpet was alkaline with pH ranging from 8.3 to 8.8 and EC varied from 0.15 to 0.18 d S m⁻¹. The water was, however fit for irrigation and not potable as per the standards (Class A) prescribed by the Indian Standards Institution for inland surface waters subject to pollution hazards (ISI-2296-1982).

The properties of groundwater also were influenced by the disposal of USW at both Amberpet and Golkonda landfill sites. The pH and EC showed an increase and the load of total, dissolved and suspended

solids increased in the waters of the wells situated within a distance of 200 meters from the fringe of the landfill site. The total hardness and alkalinity values were far above the prescribed ISI (1983) and WHO (1984) standards. Califorms were however not detected in the water ruling out the possibility of direct contamination with fresh human excreta. The BOD and COD also increased beyond the prescribed limits in some wells.

Pot culture studies conducted to evaluate the manurial value of USW and their impact on concentration of micronutrients and heavy metals in soil and their uptake by maize have shown that application of USW upto 33 t ha^{-1} with recommended N, P and K increased the dry matter yield of plants but not at 44 t ha^{-1} . In general, plant uptake of Fe and Cu decreased and Mn and Zn increased due to application of USW. Manganese uptake was however reduced at higher (44 t ha^{-1}) level of USW addition. Likewise, increased Pb, Ni and Co uptake was recorded while Cd and Cr, though present in the soil was not absorbed. Eventhough the uptake of heavy metals did not exceed the dietary limits, this should be monitored carefully, as pollution hazard may be encountered in the long run. With FYM addition at comparable levels no such effects were evident. Significant increase in pH, EC, total and extractable (DTPA) micronutrients and heavy metals in soil were recorded after harvest of maize due to USW application, where as

with FYM only micronutrient (total and DTPA extractable) contents was increased in soil. The total micronutrient and heavy metal concentration in soil were in the decreasing order as follows: Fe > Mn > Pb > Cr > Zn > Cu > Ni > Co > Cd.

A survey conducted to study the impact of application of fresh USW on soil properties and plant uptake of micronutrients and heavy metals in farmers fields revealed significant changes in the textural character of soil with an increase in content of silt and clay and proportional decrease in coarse fractions as result of USW use. The pH increased from 6.05 to 8.52 and EC from 0.4 to 2.5 d S m l^{-1} . Exchangeable sodium percentage increased from 0.18 to 20.66. The organic carbon and available N, P and K also increased significantly besides the CEC. The total soil Fe content decreased whereas Zn, Mn, Cu, Pb, Ni, Co, Cd and Cr contents increased several folds. Likewise the extractable (DTPA) micronutrients and heavy metals also increased to varying levels. Some of microelements increased (Zn, Cu and Pb) in soil to toxic levels and therefore posed a pollution threat through their entry in the food chain. This can be due to increased absorption by food crops and by their contamination of ground and surface waters. The micronutrient and heavy metal concentration of plants collected from farmers'

field varied widely among the plant species and plant parts. In general, the content of Zn, Cu, Pb and Ni were elevated in some plant species pointing to a potential pollution hazard through their entry into the food chain. The concentration of Fe, Mn, Cr, Co and Cd did not exceed the toxic limits. Eventhough the distribution of heavy metals and micronutrients in different plant parts varied amongst the plant species, in many plants the roots tended to absorb and retain them more than foliage or above ground plant parts.

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ABSTRACT

The urban solid wastes generated in Hyderabad city are being disposed off by landfill at three landfill sites viz., Amberpet, Golkonda and Autonagar and also utilized directly by the farmers as a manure. The impact of disposal of urban solid wastes generated in Hyderabad as either landfill or as a manure, on soil properties and ground and surface water quality was investigated.

The solid wastes generated in Hyderabad were highly heterogenous and contained comparatively less of plastics, paper, metal and rubber as compared to the waste characteristics reported in other developed countries. The content of gravel, soil and dust were, however, more in the wastes. The wastes were alkaline in pH and the organic carbon content ranged from 3.4 to 6.3 per cent. With the COD ranging from 89.0 to 168.0 mg g⁻¹. The content of soluble salts was also high and variable and contained heavy metals and micronutrients.

The characteristics of soil profiles under the urban waste dumps in one of the landfill sites (Amberpet) were studied. The textural characteristics of the soil at various depths were modified due to solid waste overlay. The other important soil characteristics, pH, EC, organic carbon, CEC, exchangeable cations, total and available nutrients content, water soluble ions, ESP, total heavy metals and DTPA-extractable trace metals increased substantially but the total micronutrients decreased as compared to control.

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A bioassay procedure evolved to assess the impact of waste disposal on soil profile characteristics clearly demonstrated that the seeds of Italian millet failed to germinate in soils of some depths in soil profiles where USW were disposed. This was mainly due to high EC and ESP of soils.

Analysis of surface runoff water samples at the Amberpet landfill site for pollution causing constituents have shown that the water quality is altered significantly due to the land disposal of USW. The water was fit for irrigation and not suitable for drinking purpose by animals and man. The quality of underground water (Bore and open wells) sources was assessed at both Amberpet and Golkonda landfill sites. The groundwaters at both the landfill sites were polluted and are unfit for human consumption and domestic use but could be used for irrigation only.

Land application of urban solid wastes upto 33 t ha⁻¹ benefited the maize crop but not at 44 t ha⁻¹. The uptake of Pb, Ni and Co by maize increased due to USW addition but not with FYM and soil characteristics like pH, EC, total and DTPA-extractable trace metals increased due to USW but not to any significant extent with FYM.

The effect of continuous application of fresh USW on soil properties and uptake of microelements by some crops in farmers' fields showed that the soil properties like texture, colour, pH, EC, total and extractable micro-elements increased substantially and some of them attained toxic limits. Several crop plants absorbed the micro-elements in increasing concentration and some of these (Zn, Cu, Pb and Ni) were absorbed actively by the plants which indicates the possible pollution threat with their entry in the food chain. Chromium and Cadmium were, however, not detected, but lead which was absorbed tended to remain in the roots and was not translocated to edible plant parts like fruits and grains. The concentration of trace elements in plants varied widely depending on plant species and plant parts.

LIST OF ACRONYMS AND ABBREVIATIONS

AFW	: Autonagar fresh waste
Ag NO ₃	: silver nitrate
Al	: aluminium
APHA	: American Public Health Association
ASW	: Amberpet stabilized waste
B	: boron
BaCl ₂	: barium chloride
BOD	: biochemical oxygen demand
btu/lb	: British thermal unit per pound
C	: carbon
°C	: degree centigrade
Ca	: calcium
CaCl ₂	: calcium chloride
CaCO ₃	: calcium carbonate
Cd	: cadmium
Cd/Zn	: cadmium zinc ratio
CEC	: cation exchange capacity
Cl	: chloride
cm	: centimeter
Cmol (p+)kg ⁻¹ soil	: centimole per kilogram (cations)
C/N	: carbon nitrogen ratio
Co	: cobalt
CO ₂	: carbondioxide
CO ₃	: carbonate
COD	: chemical oxygen demand

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Cr	: chromium
Cu	: copper
DAS	: days after sowing
DO	: dissolved oxygen
$d S m^{-1}$	: deci siemen per meter
DTPA	: diethylene triamine penta acetic acid
dw	: dry weight
EC	: electrical conductivity
EDTA	: ethylenediaminetetraacetate
ESP	: exchangeable sodium percentage
F	: fluoride
Fe	: iron
Fig.	: figure
FUSW	: fresh urban solid waste
FYM	: farmyard manure
g	: gram
$g dish^{-1}$	: gram per dish
GFW	: Golkonda fresh waste
GSW	: Golkonda stabilized waste
H	: hydrogen
ha	: hectare
HCl	: hydrochloric acid
$HClO_4$	: perchloric acid
HCO_3	: bicarbonate
HNO_3	: nitric acid
H_2SO_4	: sulphuric acid

ICMR	: Indian Council of Medical Research Institution
ISI	: Indian Standards Institution
K	: potassium
$K_2Cr_2O_7$	: potassium dichromate
kg	: kilogram
$kg\ ha^{-1}$	: kilogram per hectare
K_2O	: potash
L	: liter
l	: loam
ls	: loamy sand
m	: meter
m^3	: cubic meter
Mg	: magnesium
mg	: milligram
$mg\ g^{-1}$	: milligram per gram
$mg\ kg^{-1}$	: milligram per kilogram
$mg\ l^{-1}$	: milligram per litre
ml	: milliliter
mm	: millimeter
Mn	: manganese
MO-Alkalinity	: methyl orange alkalinity
MPN	: most probable number
MSW	: municipal solid waste
N	: nitrogen
Na	: sodium
ND	: not detected

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NEERI	: National Environmental Engineering Research Institute
NH ₄	: ammonia
NH ₄ OAc	: ammonium acetate
Ni	: nickel
NO ₃	: nitrate
NTU	: nephelometric turbidity unit
O	: oxygen
OC	: organic carbon
OM	: organic matter
P	: phosphorus
P-Alkalinity	: phenolphthalein alkalinity
Pb	: lead
P ₂ O ₅	: phosphorus pentaoxide
PO ₄	: phosphate
ppm	: parts per million
S	: sulphur
s	: sand
scl	: sandy clay loam
Se	: selenium
sl	: sandy loam
SO ₄	: sulphate
Sm ⁻¹	: siemen per meter
Sn	: tin
t	: tonne
TA	: total alkalinity
t acre ⁻¹	: tonne per acre

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TDS	: total dissolved solids
TEA	: triethanolamine
TH	: total Hardness
t ha ⁻¹	: tonne per hectare
TS	: total solids
TSS	: total suspended solids
USW	: urban solid waste
viz.	: namely
WHO	: World Health Organisation
Zn	: zinc
%	: per cent
>	: greater
<	: less
ug	: microgram
u S m ⁻¹	: microsiemen per meter