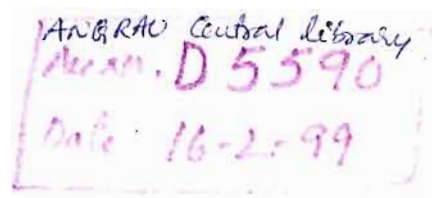


# IMPACT OF SEWAGE IRRIGATION ON SOIL CHEMICAL PROPERTIES



By  
RAM MOHAN REDDY GANTA  
B.Sc(Ag)

THESIS SUBMITTED TO THE  
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY  
IN PARTIAL FULFILMENT OF THE REQUIREMENTS  
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE  
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*Dedicated to*

*my loving brother*

*GANTA SURESH REDDY*

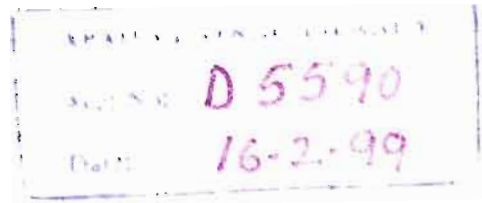
*who died in a sea accident, leaving me alone*

*and*

*my grand father*

*Late GANTA CHENCHALAI REDDY*


*who was a Freedom Fighter.*



## CERTIFICATE

Mr. RAM MOHAN REDDY GANTA has satisfactorily prosecuted the course of research and that the thesis entitled "IMPACT OF SEWAGE IRRIGATION ON SOIL CHEMICAL PROPERTIES" 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.

Date : 16/2/98.

  
(Dr. K. JEEVAN RAO)  
Major Advisor

## CERTIFICATE

This is to certify that the thesis entitled "IMPACT OF SEWAGE IRRIGATION ON SOIL CHEMICAL PROPERTIES" submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE IN AGRICULTURE of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr. RAM MOHAN REDDY GANTA under our 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. The published part has been fully acknowledged. All assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.

  
(Dr. K. JEEVAN RAO) 16/8/98.

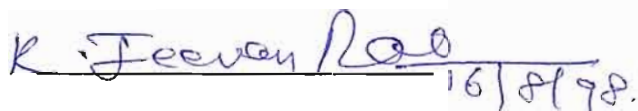
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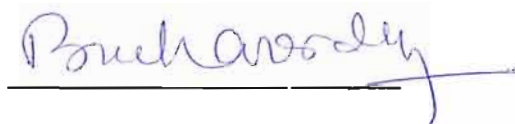
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## DECLARATION

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Date :



(RAM MOHAN REDDY GANTA)

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Place :

**(G. RAM MOHAN REDDY)**

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## LIST OF SYMBOLS AND ABBREVIATION

BOD	:	Biological Oxygen Demand
CD	:	Critical difference
Cr	:	Cromium
Co	:	Cobalt
CO <sub>2</sub>	:	Carbon dioxide
Cu	:	Copper
oC	:	Degree centigrade
DO	:	Dissolved Oxygen
dSm <sup>-1</sup>	:	DeciSiemen per meter
<i>et al</i>	:	and others
Fe	:	Iron
Fig	:	Figure
Fe	:	Iron
g	:	gram
i.e.,	:	which is to say, in other words
kg ha <sup>-1</sup>	:	kilograms per hectare
mg kg <sup>-1</sup> soil	:	milligrams per kilogram soil
Mn	:	Manganese
Ni	:	Nickel
pb	:	Lead
ppm	:	Parts per million
SE	:	Standard error
<i>viz.</i> ,	:	namely
Zn	:	Zinc
<	:	less than
%	:	per cent
@	:	at the rate of

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### **ABSTRACT**

Raw sewage water of Hyderabad city entering into Maize Research Station, Amberpet was characterised and its effect on characteristics of soils was studied as an attempt to understand the use of sewage water for irrigation to crop plants.

The characterisation of this sewage water indicated that it has beyond tolerable limits of soluble salt content, COD, cadmium and chromium making it necessary to treat it before using for crop irrigation. On the otherhand the other parameters such as pH, BOD, DO, N, P, K and micronutrients content were within safe limits.

The continuous use of this sewage water for irrigation resulted in increased content of silt and clay of the soil resulting in higher CEC. The essential nutrients such as N, P, K, Ca, Mg were high in these soils and are useful for availability to plant.

The accumulation of DTPA extractable and total micronutrients and heavy metals was observed in sewage water irrigated plots. Similarly, their content with increased depth was less due to low mobility of these metals. The contents of heavy metals in plant and seed of maize were within the toxic limits. The uptake of these micronutrients and heavy metals was considerable in maize plants at harvest but no detrimental effect on maize plant and yield was observed.

---

# *INTRODUCTION*

---

## CHAPTER I

### INTRODUCTION

India is predominantly an agricultural country with a population of more than 92 crores and will cross 100 crores by the end of 2000 A.D. The food production is around 198 million tonnes (1996-97) (The Hindu Survey of Indian Agriculture, 1997) and this has to be increased to 240 million tonnes by the end of century. Part of the food production comes from the irrigated lands and the rest from the dry lands which occupy nearly 75 per cent of the cultivated area.

Water is an essential input for production. It is a renewable natural resource. The total volume of water in the hydrological cycle on the globe is constant. It is feared that in future water may become the most limiting factor for producing enough food, feed, fibre and fuel for the projected population.

The quantum of water available for agriculture is dwindling day by day because of increase in demand on the limited water resources by industrial sector & urbanisation. In addition to this, the present trend to grow high value crops in place of food crops has further aggravated the problem of water availability for food crops. The industrial & urban sectors not only utilise the available water but also discharge considerable amount of waste water into nearby lakes, tanks, rivers, seas, land masses, thus polluting the environment. Proper disposal of sewage has always been a problem in urban areas.

In view of this, reuse of waste waters in agriculture has become a necessity. In many arid and semi arid countries around the world which are faced with acute shortage of water, the reuse of sewage water in agriculture is considered as an important strategy in conserving the water reserves and reducing water pollution problems.

Application of sewage to agricultural land is viewed with concern and it has become a challenge to dispose it off in a way that is environmentally acceptable, economically feasible and is least hazardous to human health. The raw sewage water (Sewage) and sludge contain beneficial elements (such as N,P,K) as well as toxic metals (such as Cd, Cr, Pb, Ni, Zn). However these waters are being used for irrigation purpose for forage and vegetable crops in most of the metropolitan cities in India.

In India the total waste water generated per annum from 200 cities is about 2600 M m<sup>3</sup>. In Hyderabad alone about 250 million litres per day is being generated (Hyderabad Municipal Waste Water and Sewerage Board). Most of the sewage water is disposed off untreated.

The maize Research Station, Amberpet, Hyderabad was established in 1953 in an area of 127 ha and was recognised under all India coordinated maize improvement project in 1957 by ICAR. This Research Station is catering the needs of off season winter nursery programme. The congenial climate required for off season winter nursery programme is not available any where in the country other than Amberpet. Since 1957 the Maize Research Station Amberpet is being continuously irrigated with Hyderabad city sewage for growing maize crop. Raw sewage is being used

for irrigation and the quantity of sewage used is as per water requirement of the crop.

So far most of the studies were carried out with sewage irrigation in India are on crops like Vegetables and rice. The information on maize crop, irrigated with sewage water is meager. More over, Amberpet Research Station lack the information on effect of long term sewage irrigation on soil properties. Hence the present studies were undertaken to study the long term impact of sewage irrigation on soil chemical properties with the following objectives:

1. To characterise the sewage water for important chemical parameters.
2. To study the impact of sewage irrigation on soil chemical properties.
3. To study the uptake of micronutrients and heavy metals by maize plant.

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*REVIEW OF LITERATURE*

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## CHAPTER II

### REVIEW OF LITERATURE

In India total waste water generated per annum from 200 cities is about 2600 M m<sup>3</sup>. About 65 to 70 per cent of waste water does not get any treatment (Kaul *et al.*, 1989). Due to lack of treatment and improper mode of disposal, waste water, when disposed off on land or in natural streams, causes physical, chemical and biological hazards. Application of sewage waters to agricultural land is being viewed with concern and it has become a challenge to dispose it off in a way that is environmentally acceptable, economically feasible and is least hazardous to human health.

The available literature on the characteristics of sewage water and the impact of sewage irrigation on soil chemical properties and uptake of micro nutrients and heavy metals by plants are reviewed.

#### 2.1 CHARACTERISTICS OF SEWAGE WATER

Application of municipal waste water to agricultural land has been recognised as a desirable method of its disposal. Municipal wastes usually have high contents of several heavy metals (Van Loon and Lichwa, 1973; Kirkham, 1974; Larson *et al.*, 1975) and their continuous application to soil may result in enrichment of heavy metals in the top soil (Anderson and Nilson, 1973). The presence of large amount of carbonates and bicarbonates or total solids in waste water may also make these unsuitable for long term application to agricultural lands on the other hand the raw sewage water contain beneficial elements (such as N, P, K).

### 2.1.1 Physico-chemical and Chemical Characteristics

Lakshmi Menon and Bhattacharya (1988) conducted a study on sewage effluents obtained Okhla waste water treatment plant, Delhi and reported that pH varied from 7.0 to 7.5 in raw sewage.

Kalra *et al.* (1992) evaluated sewage effluent for crop irrigation at the main sewage treatment plant at Amberpet, Hyderabad and observed that the pH values of all the waters are within permissible range for irrigation use with pH values for sewage at Secunderabad, Amberpet, Chaderghat, Mallacheruvu ranges from 6.9- 7.5, 6.9-7.5, 6.9-7.5 and 7.1 - 8.0 respectively.

Mosetti *et al.* (1994) reported that the pH values were always alkaline in all samples collected in Jayanthi nalla and river panchanganga of Kothapur. However, it was reduced to 7.5 of X<sub>9</sub> and X<sub>10</sub> river samples.

Shrabanisom *et al.* (1994) undertaken a work to assess the quality of sewage effluents discharged from Howrah sewage treatment plant for irrigation and observed that the sewage effluent was slightly alkaline in reaction, both in summer and monsoon. pH ranged from 7.3 to 7.7. According to the tolerance limits of pH for irrigation and fisheries which vary between 6-9 (Desai *et al.*, 1990), the pH of the effluents was within the permissible limits in respect of its use of agricultural land.

Mitra and Gupta (1997) collected ground water of shallow and deep tube wells from sewage irrigated farm areas of eastern fringe of the Calcutta city and reported that in all the cases, pH was alkaline in reaction irrespective of depth and in general it ranged between 8.1 and 8.7. As Biswas (1991)

specified limit, in 70 per cent cases pH was above the BIS desirable limit and in all (100 %) the cases pH was above the WHO drinking water standard.

Manoharan and Subramanyam (1992) analysed domestic sewage collected from oxidation pond in the pumping station of Golden rock, Tirucharapally and reported that pH in the domestic sewage was 7.35.

### **Electrical Conductivity (EC)**

Kale *et al.* (1992) evaluated sewage effluent for crop irrigation of the main sewage treatment plant at Amberpet, Hyderabad and observed that the EC values for sewage of Secunderabad, Amberpet, Chadarghat were 1.7, 1.3 and 2.6 dS m<sup>-1</sup> respectively and reported that these values are within the permissible limits for crop irrigation. He also noted that EC of sewage samples were higher than that of water from the village wells. This clearly indicated the need for proper crop selection with respect to salt tolerance, regular monitoring of salt concentration in the soils and need for proper irrigation management.

Mitra (1993) in his investigation on sewage water indicates that content of soluble salt in raw sewage water and adjacent irrigated soil decreases along the channel, therefore, it is expected that soluble salt entered into ground water through vertical movement (leaching) from the soil as well as from bottom sludge, which contains high amounts of soluble salt in sewage channel.

Shrabani Som *et al.* (1994) undertaken a work to assess the quality of sewage effluents discharged from Howrah Sewage treatment plant for irrigation and observed that EC values varied between 1.5 and 1.76 dS m<sup>-1</sup> in summer and 1.52 and 1.71 dS m<sup>-1</sup> in monsoon. Raw Sewage water had maximum salt concentration during the summer, but in monsoon, primary treated effluent showed maximum accumulation of salts. On the basis of united States salinity diagram (U.S. Salinity laboratory staff, 1954), the EC was within the critical limit.

Mitra and Gupta (1997) collected ground water of shallow and deep tube wells from raw sewage irrigated farm areas of eastern fringe of the Calcutta city and reported that on the basis of E.C which varied from 1.9 to 3.5 dS m<sup>-1</sup>, the ground water may be restricted for irrigation purpose.

Lakshmi Menon and Bhattacharya (1988) reported EC range of 1.02 to 1.5 mhos cm<sup>-1</sup> in the raw sewage obtained from Okhla waste water treatment plant, Delhi as 1.02 to 1.5 mhos cm<sup>-1</sup>

### **Total Dissolved Solids (TDS)**

The total dissolved solids of sewage water samples collected at Sheeladhar institute experimental farm were very high ranging from 188.2 to 432.4 mg L<sup>-1</sup> because domestic and city effluents which collect through surface drain find their way into city disposal system of Allhabad (Mishra *et al.*, 1992)

Shrabani Som *et al.* (1994) assessed the quality of sewage effluents discharged from Howrah Sewage treatment plant for irrigation and observed

that TSS and TDS were maximum (707.6 and 1820.3 mg L<sup>-1</sup>, respectively in summer and 618.2 and 1620.9 mg L<sup>-1</sup>, respectively in rainy season) for raw sewage water and minimum (78.5 and 64.6 mg L<sup>-1</sup>, respectively in summer and 613.8 and 642.1 mg L<sup>-1</sup> respectively in rainy season) in the sewage effluent after secondary treatment. All the values after treatment were within the maximum recommended limit (1500 mg L<sup>-1</sup>) for land irrigation (Indian Standards, 1982).

Mitra and Gupta (1997) reported that TDS in raw sewage irrigated farm areas of Calcutta city ranged between 840 and 1320 mg L<sup>-1</sup> on the basis of BIS (1991) Drinking Water Specification Prescribed Limit, TDS in all the ground water was above the prescribed limit for drinking purpose, and that situation may favour gastro, intestinal diseases.

### **Chemical Oxygen Demand (COD)**

Lakshmi Menon and Bhattacharya (1988) analysed sewage effluents obtained from Okhla Waste Water treatment plant Delhi and reported that COD ranged from 247.5 to 305 mg L<sup>-1</sup>.

Manoharan and Subramanyam (1992) reported that COD in the domestic sewage collected from oxidation pond of Golden road, Tirucharapally was 90 mg L<sup>-1</sup>.

Mitra and Gupta (1997) reported that COD was low in all the samples collected from sewage irrigated farm areas of Calcutta city.

## Biological Oxygen Demand (BOD)

NEERI (1985) reported that sewage BOD varies considerably within a range of 200 to 500 mg L<sup>-1</sup> for irrigation purposes.

Lakshmi Menon and Bhattacharya (1988) reported that BOD levels in the sewage effluents ranged from 108.5 to 140 mg L<sup>-1</sup> at Okhla sewage treatment plant Delhi.

Shrabhani Som *et al.* (1994) undertaken a work to assess the quality of sewage effluents discharged from Howrah Sewage plant for irrigation and observed that BOD and COD decreased from 165.5 (raw) to 34.8 mg L<sup>-1</sup> (after secondary treatment) and 279.2 (raw) to 75.6 mg L<sup>-1</sup> (after secondary treatment), respectively. Similarly decrease in BOD (from 188.7 to 33.2 mg L<sup>-1</sup>) and COD (284.1 to 76.8 mg L<sup>-1</sup>) was also observed for monsoon season.

Hosetti *et al.* (1994) reported that the Biological oxygen demand (BOD) level of the Jyanthi nalla at Kothapur varied between 308 mg L<sup>-1</sup> to 417 mg L<sup>-1</sup>.

## Dissolved Oxygen (DO)

Manoharan and Subramanyam (1992) reported that DO as 2.8 mg L<sup>-1</sup> in sewage water collected from the oxidation pond, at the pumping station of Golden rock, Tirucharapally.

Hosetti *et al.* (1994) undertaken investigation to assess the physico-chemical characteristics of Kalamba lake, Jayanthi Nalla and river

Panchaganga at Kolhapur and evaluate the impact on the river water quality. They reported that the Dissolved Oxygen (DO) levels in Jayanthi Nalla (X<sub>1</sub> - X<sub>8</sub>) varied between 4.1 mg L<sup>-1</sup> to 5.46 mg L<sup>-1</sup>. The DO at X<sub>9</sub> samples was 7.5 mg L<sup>-1</sup> to which was further reduced to 7.1 mg L<sup>-1</sup> after the confluence of sewage into the river. The DO levels of nalla river reached saturation as in case of river. The DO level was always minimum in X<sub>4</sub> samples where tannery effluents joined the nallah.

Mitra and Gupta (1997) reported that dissolved oxygen (DO) was maximum of 8.6 mg/litre at Bantala, Calcutta city and the minimum value of 6.4 mg L<sup>-1</sup> was obtained at starting point of the channel, Topsia.

### Nitrates

Manoharan and Subramanyam (1988) reported that domestic sewage collected from the oxidation pond golden rock at Tirucharapally contain 0.3 mg L<sup>-1</sup> nitrates and 0.003 mg l<sup>-1</sup> Ammonia.

Shrabani Som *et al.* (1994) reported that concentrations of both NH<sub>4</sub>-N at Howrah sewage plant were generally higher during monsoon (26.2 - 28.5) than that during the summer (20.2 - 24.2). Within the same season, the concentration of NH<sub>4</sub>-N was the highest in raw sewage followed by that in primary treated one and the least in Secondary treated sewage. But the trend was altogether reverse in respect of NO<sub>3</sub>-N. All the observed NO<sub>3</sub>-N concentrations were lower than the maximum limit prescribed for irrigation purpose (WHO, 1984).

## Chlorides

Manoharan and Subramanyam (1988) observed that the chloride content of domestic sewage collected from oxidation pond golden rock, Tirucharapally is  $150.86 \text{ mg L}^{-1}$ .

Shrabani Som *et al.* (1994) reported that chloride concentrations at Howrah were generally higher during summer ( $3.6 - 4.0 \text{ mg L}^{-1}$ ) in comparison to monsoon ( $1.9 - 1.9 \text{ mg L}^{-1}$ ). All the observed concentrations were within the tolerable limit ( $4-10 \text{ mg L}^{-1}$ ) for agricultural use (Indian Standards (IS, 1982).

Mitra and Gupta (1997) reported that average concentration of chloride was  $422.7 \text{ mg L}^{-1}$  and particularly at higher level in the water from shallow tube well collected from raw sewage areas of Calcutta city. It is observed that chloride concentration decreases along the channel with the decreases of chloride level in sewage water, settled sludge and adjacent sewage irrigated soil (Mitra, 1993). At all the locations chloride concentration was above the desirable limit ( $250 \text{ mg L}^{-1}$ ) as prescribed by BIS (1991).

## Sulphates ( $\text{SO}_4^{-2}$ )

Shrabani Som *et al.* (1994) reported that sulphate concentration at Howrah in all the effluents were much higher than the tolerable limit ( $10-14 \text{ mg L}^{-1}$ ) for irrigation purpose (Desi *et al.*, 1990)

Mitra and Gupta (1997) reported that concentration of sulphate in the raw sewage irrigated areas of Calcutta city was  $6-9 \text{ mg L}^{-1}$  which was

### Phosphates ( $P_4^{-2}$ )

Shrabani ~~Som~~ *et al.* (1994) reported that status of available P in the raw sewage at Howrah was low to medium during both the seasons. Maximum value ( $14.1 \text{ mg kg}^{-1}$ ) was observed after secondary treatment during summer season.

Mitra and Gupta (1997) reported that concentration of phosphate in the raw sewage irrigated areas of Calcutta city was  $0.005$  to  $0.03 \text{ mg L}^{-1}$  and it was well below the desirable limit for drinking purpose.

### Potassium (K)

Shrabani Som *et al.* (1994) worked at Howrah Sewage treatment plant and observed that variation of  $K^+$  concentration in the different seasons and under different treatments was not very permanent. All the observed concentrations were much above than that observed by Devis (1980), while working with effluent from selected treatment plants. The K content ranged from  $15.8$  (rainy summer) to  $18.7 \text{ mg kg}^{-1}$  (Secondary treated, summer). These results thus revealed that the sewage effluents are rich in K.

Mitra and Gupta (1997) reported that concentration of K in the raw sewage irrigated farm areas of Calcutta was moderate ( $1.9$  to  $8.6 \text{ mg L}^{-1}$ ). It is known that moderate quantities of K do not adversely effect the use of water even though the 'European committees directive' suggest  $10 \text{ mg L}^{-1}$  as guide level and  $12 \text{ mg L}^{-1}$  as maximum admissible concentration.

well below the desirable limit. According to IS (1992), desirable limit is 200 mg L<sup>-1</sup>).

### Calcium and Magnesium

Manoharan and Subramanyam (1992) observed that Ca and Mg content are 34.06 and 23.15 mg L<sup>-1</sup> respectively in domestic sewage collected from oxidation pond in the pumping station of Golden rock in Tiruchirappally district and Divalent cations such as Ca and Mg are known to be essential for flocculation.

Shrabhani Som *et al.* (1994) undertaken a work to <sup>assess</sup> the quality of sewage effluents from Howrah sewage plant for irrigation and observed that concentration of calcium ranged from 3.8 (raw) to 3.9 mg L<sup>-1</sup> (Secondary treated) and 3.9 (Primary treated) to 4.6 mg L<sup>-1</sup> (raw) in the summer and monsoon seasons, respectively. Magnesium concentration was maximum for raw sewage water during both the seasons while minimum for secondary treated water.

Mitra and Gupta (1997) reported that concentration of Ca and Mg in the ground water collected from raw sewage irrigated farm areas of Calcutta city varied from 125 to 180 mg L<sup>-1</sup> and 45.5 to 64.9 mg L<sup>-1</sup>, respectively and which were above the undesirable limits of 75 and 30 mg L<sup>-1</sup> respectively for calcium and magnesium specified by BIS.

## Carbonates and Bicarbonates

Shrabani Som *et al.* (1994) reported that carbonates and bicarbonate concentrations at different sampling points of Howrah are 1.18-1.26  $\text{mg L}^{-1}$  in Summer and 1.31 - 1.39  $\text{mg L}^{-1}$  in monsoon and they would be rated as marginal in both the seasons. There was no residual sodium carbonate hazards from the sewage effluents.

## Sodium

Shrabani Som *et al.* (1994) reported that concentration of  $\text{Na}^+$  ranged from 3.3 (secondary treated, monsoon) to 6.1  $\text{mg L}^{-1}$  (Primary treated, summer) at Howrah sewage treatment plant.

Mitra and Gupta (1997) collected ground waters from raw sewage irrigated areas of Calcutta city, and observed that concentration of Na ranged between 76 and 250  $\text{mg L}^{-1}$ . Though no prescribed limit on Na content in drinking water seems to have been laid down but as much as 200  $\text{mg L}^{-1}$  concentration may be injurious to health. Therefore on the basis of Na concentration it can be said that ground water of eight locations out of ten, having Na concentration below the limit. In respects of 'per cent Na' ground water may be classified as good quality for irrigation.

## Sodium Absorption Ratio

Shrabani Som *et al.* (1994) reported that the SAR values of Howrah sewage treatment plant ranged from 1.3 to 2.3 and 1.3 to 2.0 in the summer and monsoon season, respectively and these values were within the critical limit (3.0) for irrigation purpose (Indian Standards - 1982).

## Micro nutrients and Heavy Metals

### Iron

The content of Fe in the sewage water collected at Shee<sup>la</sup>har Institute Experimental farm showed a range of 8.12 mg L<sup>-1</sup>. On an average the sewage water was relatively richer in Fe content. The maximum recommendation of Fe in sewage waters is 5 Mg L<sup>-1</sup> (EPA- 1973). FAO (1985) also reported 5 mg L<sup>-1</sup> as the maximum concentration of Fe in the irrigation water. The sewage waters at SDI experimental farm are not used for irrigational purposes (Misra *et al.*, 1992).

Mitra and Gupta (1997) reported that concentration of Fe in the raw sewage areas of Calcutta city varied from 0.68 to 1.26 mg L<sup>-1</sup>. All the ground water samples contained undesirable amounts of Fe for drinking purpose (BIS, 1991).

### Manganese

The Mn content of sewage water varied from 10.6 to 306 mg L<sup>-1</sup>. This constitutes the problem when added to acid soils in which the increase in level of soluble Mn could cause phytotoxicity. Recommended maximum permissible concentration of Mn is 0.2 mg L<sup>-1</sup> (Pratt 1972). Hence sewage waters at SDI experimental farm was unsatisfactory for irrigation purpose (Misra *et al.*, 1992).

Mitra and Gupta (1997) reported that concentration of Mn varied from 0.48 to 0.64 mg L<sup>-1</sup> in the sewage irrigated areas of Calcutta city and it was above the desirable limit of 0.1 (IS, 1982).

## Zinc

Zinc content in different samples collected at Sheeladhar institute experimental farm varied from 5.8 to 10 mg L<sup>-1</sup>, it was below the safe limit.

Shrabani Som *et al.* (1994) reported that zinc concentration in the sewage effluents from Howrah sewage treatment plant ranged from 10.5 to 72.0 mg L<sup>-1</sup> and it was below the maximum recommended limit (15 mg L<sup>-1</sup>) for land application (IS-1982).

Mitra and Gupta (1997) reported that in the sewage irrigated areas of Calcutta city, the average concentration of Zn ranged from 0.69 to 2.16 mg L<sup>-1</sup> and it is well below the desirable limit (BIS, 1991).

## Copper

Mitra and Gupta (1997) reported that in the sewage irrigated areas of Calcutta city, the average concentration of Cu was 0.03 mg L<sup>-1</sup> and it well below the desirable limit (BIS, 1991) for drinking purpose.

## Cadmium

The Cd content of sewage water collected from at Sheeladhar institute experimental farm, Allahabad ranged between 0.26 to 0.85 mg L<sup>-1</sup>. According to standards proposed by FAO 1985, the maximum permissible limits for Cd in irrigation water is 0.01 mg L<sup>-1</sup>. Accordingly the sewage water of SD~~A~~ Experimental farm may be rated as toxic for plants (Misra *et al.* (1992).

Shrabani Som *et al.* (1994) reported cadmium (Cd) concentration in the sewage effluents at Howrah sewage treatment plant ranged from 4.0 to 22.0 mg L<sup>-1</sup> in the summer season, while in the monsoon, it was detected only in the raw sewage water. Thus the raw sewage water contained toxic amount of Cd (22.0 mg L<sup>-1</sup>) particularly in the summer season.

Mitra and Gupta (1997) reported that the concentration of Cd was 0.001 to 0.003 mg L<sup>-1</sup> in the ground water samples collected from sewage irrigated areas of Topsia, Calcutta city and it was much below the desirable limit of 0.05 mg L<sup>-1</sup> (BIS, 1991) for drinking purpose.

### **Chromium**

The amount of chromium in sewage water collected at Sheeladha Institute Experimental farm varied from 0.28 to 0.7 mg L<sup>-1</sup> and was more than suggested maximum permissible concentration of 0.1 mg L<sup>-1</sup> chromium by FAO in irrigation water (Misra *et al.*, 1992).

Shrabani Som *et al.* (1994) reported that chromium (Cr) in the sewage effluents at Howrah sewage treatment plant was present only in the raw sewage water and it was not detected after the treatment.

Misra and Gupta (1997) reported that the concentration of Cr was between 0.002 and 0.008 mg L<sup>-1</sup> and it was detected only in the ground water collected from shallow tube wells located in sewage irrigated areas of Topsia, Calcutta City, and it is much below the desirable limits of 0.05 mg L<sup>-1</sup> for drinking purpose. (BIS- 1991).

## Lead

The limiting concentration of Pb in drinking water prescribed by WHO was  $0.10 \text{ mg L}^{-1}$ . However for irrigation water, FAO (1985) has prescribed as  $5 \text{ mg L}^{-1}$ . The sewage waters of Sheeladhar institute experimental farm, Allahabad contained  $0.70$  to  $580 \text{ mg L}^{-1}$  of pb. The concentration appears to vary from place to place because it depends on the nature of industries and domestic user (Misra *et al.*, 1992).

Shrabani Som *et al.* (1994) reported hat concentration of pb at Howrah varied from  $8.1$  to  $30 \text{ mg L}^{-1}$  in the summer and  $110$  to  $412 \text{ mg L}^{-1}$  in the monsoon.

Mitra and Gupta (1997) detected pb concentration ( $0.002$  to  $0.004 \text{ mg L}^{-1}$ ) only in the ground water samples collected from shallow tube well located in raw sewage irrigated farm areas of Topsia, Calcutta city. All the observed concentrations were much below the desirable limits ( $0.05 \text{ mg L}^{-1}$ ) for drinking purpose (BIS, 1991).

## 2.2 PHYSICO-CHEMICAL CHARACTERISTICS OF SOILS

Soil is not only a medium for plant growth but it is also a sink for waste solids and liquids. Sewage wastes may be spread, dumped sprayed, ponded, injected or in same way deposited on or into the soil. The effect of the Sewage Waste Waters on the different properties of Soils depends on (i) The variations in the physico-chemical characteristics of the sewage water (ii) The soil composition. The former is attributed to the differences in the dietary habits of the locality, population density and the biproduct

impurity of the industrial units (Singh *et al.*, 1973). The sewage waste waters not only contain the municipal waste but also effluents from various industries. Although Sewage Waste Water contains some amount of toxic metals but there are large quantities of essential nutrients, which are required for plant growth contained in it.

### pH

Azad *et al.* (1987) conducted irrigation experiments with sewage waste water around 'Budha Nullah', Ludhiana Punjab and showed that pH of surface soils (0-15 cm) ranged from 7.9 to 8.3 and 8.6 to 9.0 at sites irrigated with tube well and sewage waste waters respectively. On the otherhand the pH of sub surface layers was generally higher as compared to surface soils.

Kuhad *et al.* (1989) showed that profiles receiving sewage water irrigation at Ali, Sharam, Panipat and Sonapat in Haryana had alkaline pH and the pH increased from 7.43 to 7.8, 7.9 - 7.94, 8.25 - 8.27, 8.05 to 8.35 respectively from A<sub>p</sub> to c horizon. The higher content of Mo in Panipat, Sonapat soils might be due to higher pH values. Tiwari *et al.* (1996) observed that soils irrigated with treated sewage water had relatively higher pH (8.0) as compared with corresponding values (7.5) for soils irrigated with tube well water at BHU, Varanasi, U.P.

The physico-chemical characteristics of sewage fed soils of Calcutta showed that soils are neutral to slightly alkaline (pH 7.3 to 7.5) in reaction (pH 7.3 to 7.5) (Maiti *et al.*, 1992).

Bhupal Raj *et al.* (1997) reported that soils along the Musi river, Hyderabad irrigated with sewage and effluent water were slightly acidic to alkaline in soil reaction (6.0 to 8.0) and normal to slightly saline in salt content. The mean soil pH of subsurface soil samples (7.74) was slightly more than that of surface samples (7.28).

### Electrical Conductivity (EC)

Electrical conductivity of the surface soil layers ranged from 0.15 to 0.30 in sewage fed soils around 'Budha Nallah' Ludhiana, Punjab and it was between 0.15 to 0.25 m mho/cm in normal soils. The EC of sub surface soils decreased in both types of soils which might be due to leaching of salts out of these depths in light textured soils (Azad *et al.*, 1987).

Sharma *et al.* (1994) have analysed soils taken from experimental farm of University at Hisar receiving sewer water for the last 10 years and from a field adjoining it but irrigated with canal water and observed that EC of sewage water irrigated surface soils is  $0.5 \text{ dS m}^{-1}$  and EC of associated subsurface soil is 0.9 whereas the EC of adjoining canal water irrigated surface soil is 0.5 and EC of associated subsurface soil is  $0.7 \text{ dS m}^{-1}$ .

Tiwari *et al.* (1996) observed that EC of soils irrigated with treated sewage water were relatively higher ( $0.2 \text{ dS m}^{-1}$ ) as compared with the corresponding values for soils irrigated with tube well water ( $0.19 \text{ dS m}^{-1}$ ) at Banaras Hindu University, Varanasi, U.P.

The salt content in the lowland sewage fed soils of Calcutta is more than the upland soils. The subsurface soils of upland have higher salt content

(EC  $1.84 \text{ dS m}^{-1}$ ) than the surface soils (EC  $0.55 \text{ dS m}^{-1}$ ) Whereas the reverse is the case for the low land soil which is due to the high capillary action (Maiti *et al.*, 1992).

### **Sand, silt and clay**

Azad *et al.* (1987) reported that percentage distribution of sand, clay and silt fractions in the surface layer (0-15 cm) of normal soils ranged between 70.5 - 82.9, 5.3-13.8, 10.8-22.9 per cent respectively where as the corresponding percentage distribution in the sewage fed soils was 62.7-79.2, 7.7-20.5 and 9.5-29.6 per cent respectively.

Singh *et al.* (1994) reported that the clay per cent increased from 26 to 27 per cent, 26.4 to 27.4 per cent and 26.2 to 27.2 per cent in three profiles exposed at Varnasi as the depth increased from 0-0.18 to 0.60-0.70 mts.

### **Cation Exchange Capacity (CEC)**

Kuhad *et al.* (1989) showed that CEC increased with depth in profiles receiving sewage water irrigation exposed at Ali, Sharan and Sonepat and their corresponding values were 5.9 - 12.1, 6.4- 12.5, 5.6-8.5 c mol ( $\text{P}^+$ )  $\text{kg}^{-1}$  from  $A_p$  to  $C_2$  horizons respectively.

Maiti *et al.* (1992) characterised the sewage effluents and sludges of the Calcutta city and reported that higher values of CEC are found in winter than in the monsoon. In winter season the CEC of Topsia and Palga danga regions are 26.3 and 22.1 whereas the corresponding values in monsoon

reason are 19.4 and 19.8. Variation in cation exchange capacity in different seasons may be due to the variation in mineral composition.

Singh *et al.* (1994) reported that in three profiles exposed at Varnasi, the CEC increased from 14.88 to 15.54, 14.52 to 15.46 and 14.56 to 15.34  $\text{cmol (P}^+) \text{kg}^{-1}$  with the increase in depth from 0-0.18 to 0.6-0.7 m. They also observed the increase in clay content with depth in all the three profiles.

### Exchangeable Calcium and Magnesium

Irrigation experiments with sewage waste water 'Budha Nallah', Lidhiana, Punjab showed that Calcium carbonate varied widely from 2.6 to 8.6 per cent in 0-15 cm and from 3.3 to 9.8 per cent in 15-30 cm soil layers in sewage fed soils whereas the content of  $\text{CaCO}_3$  in normal soils varied from 1.3 to 1.66 and 2.8 to 7.9 per cent in the corresponding layers. The  $\text{CaCO}_3$  content in the 0-15 cm layer of sewage treated soils was significantly higher than in the corresponding layer of tube well treated soils. There were significant differences at lower depths. The content of  $\text{CaCO}_3$  was generally higher in subsurface layers. Further more the sewage feed soils contained higher content of  $\text{CaCO}_3$  in both the layers in comparison to the normal soils. This might be due to higher calcium content of sewage water canal (Azad *et al.*, 1987).

Lakshmi Menon and Bhattacharya (1988) have conducted a study on the effect of movement of available calcium and magnesium in soil columns receiving raw sewage, primary and secondary treated sewage and reported that the surface layer of the raw sewage treated column contained

calcium (1714 ppm) which was significantly higher than the original soil concentration of  $144.2 \text{ mg kg}^{-1}$ . This was due to the binding of calcium with fulvic acid which is an important constituent of sewage. On the other hand magnesium concentration in surface layers of soil column increased with sewage treatment, because magnesium also showed the ability to form chelates with organic matter. However elevated levels of magnesium were found in the surface layers. While calcium was concentrated at the bottom 45-60 cm layer. They showed that calcium has a high negative correlation with available magnesium due to competition between calcium and magnesium for binding sites.

Very low  $\text{CaCO}_3$  content of profiles exposed at Panipat, Sonapat, in Haryana were reported due to physiographic and drainage variations and due to complete leaching of calcium carbonate from the profiles. On the other hand the data shows that the  $\text{CaCO}_3$  content in the surface layers of Ali, and Shran profiles is very low but in subsurface layers  $\text{CaCO}_3$  content is 10.75 and 8.0 per cent respectively (Kuhad *et al.*, 1989).

Singh (1994) showed that the  $\text{CaCO}_3$  content of three profiles of vegetable cultivated fields around Varanasi, U.P. receiving untreated municipal sewage increased with depth. The  $\text{CaCO}_3$  content of profile I, II and III increased from 0.8 to 1.80, 7.2 to 19.0, 7.6 to 18.6  $\text{g kg}^{-1}$  respectively with the increase in depth from 0 to 0.7 mts. Maiti *et al.* (1992) showed that exchangeable  $\text{Ca}^{+2}$  contents of upland sewage fed soil in 0-15 cm and 15-30 cm depths are 14.3 and 19.3  $\text{mol (P}^+) \text{ kg}^{-1}$  and the corresponding

low land values are 11.5 and 15.1  $\mu\text{mol (P}^+) \text{ kg}^{-1}$ ,  $\text{Ca}^{+2}$  is the dominant cation in the exchangeable complex followed by  $\text{Mg}^{+2}$ ,  $\text{Na}^+$  and  $\text{K}^+$ .

Calcium carbonate content ranged from 10-40  $\text{g kg}^{-1}$  in the top layer (0-30 cm) while it ranged from 20 to 60  $\text{g kg}^{-1}$  in sub soil (30-60 cm) in soils irrigated with sewage and effluent water along Musi River, Hyderabad (Bhupal Raj *et al.*, 1997)

### **Exchangeable sodium**

Maiti *et al.* (1992) reported that the exchangeable sodium content in some sewage fed soils of Calcutta is more in the subsurface (0.6  $\mu\text{mol (P}^+) \text{ kg}^{-1}$ ) than on the surface layers (0.4  $\mu\text{mol (P}^+) \text{ kg}^{-1}$ ).

### **Exchangeable potassium**

Maiti *et al.* (1992) reported that exchangeable  $\text{K}^+$  in both the surface and subsurface sewage fed soils almost remained constant. On the other hand the exchangeable  $\text{K}^+$  content of surface low land sewage fed soil is 0.1 and subsurface  $\text{K}^+$  content is 0.3  $\mu\text{mol (P}^+) \text{ kg}^{-1}$ .

### **Organic carbon**

Azad *et al.* (1987) reported that organic matter content in 0-15 cm soil layers ranged from 0.31 to 3.49 per cent and 0.23 to 1.45 per cent in sewage fed and normal soils respectively in Ludhiana, Punjab. Although it decreased in lower depths under both the conditions, yet sewage treated soils contained significantly more amount of organic matter at all depths. Higher

amount of OM in sewage waste water fed soils appears to be a consequence of the higher content of organic matter in sewage waste water.

Maiti *et al.* (1992) reported that both the upland and low land sewage fed soils of Calcutta contained high amount of organic matter. Further he added that OC content decreased with depth from 0-30 cm. The OM content in upland 0-15, and 15-30 cm depths is 1.32 and 1.20 per cent whereas the O M content of low land at 0-15 and 15-30 cm depths is 1.31 and 1.16 respectively.

The organic carbon content of soils irrigated with sewage water was relatively higher ( $599 \text{ kg}^{-1}$ ) as compared with the corresponding values for soils irrigated with tube well water ( $3.699 \text{ kg}^{-1}$ ) at Banaras Hindu University, U.P. Higher organic carbon content of the soils irrigated with sewage water may be due to higher organic load (higher BO $\emptyset$ ) of treated sewage water (Tiwari *et al.*, 1996).

The OC content of sewage irrigated soils of Sheeladhar Institute Experimental farm, Allahabad is 1.1 per cent where as the corresponding organic carbon content for non sewage irrigated soil is 0.45 per cent.

The organic carbon content was  $25 \text{ g kg}^{-1}$  in top soil and  $15 \text{ g kg}^{-1}$  in sub soil along the Musi river around Hyderabad and Ranga Reddy districts (Bhupal Raj *et al.*, 1997)

### Available nitrogen

Azad *et al.* (1987) in his irrigation experiments with sewage waste water in some villages around 'Budhan Nallah' Ludhiana, Punjab reported that the normal soils contained very low to low amounts of available nitrogen. Which ranged from 22 to 84 mg L<sup>-1</sup> and 11 to 68 mg L<sup>-1</sup> surface and sub surface layers. But soils fed with sewage waste water had low to medium available nitrogen which ranged from 39 to 212 mg L<sup>-1</sup> in the surface layers and 17 to 123 mg L<sup>-1</sup> in sub surface layers. The average amounts of available nitrogen in the surface layer of the soils irrigated with and without sewage waste waters were  $97.5 \pm 4.9$  mg L<sup>-1</sup> and  $57 \pm 5.8$  mg L<sup>-1</sup> respectively. This is apparently associated with build up of organic matter due to continuous application of sewage waste waters. Decrease in nitrogen content with depth of the soil also followed the pattern of organic matter. Significant differences were observed only upto 15-30 cm soil layer.

Maiti *et al.* (1992) observed that the available N content in sewage fed soils of Calcutta city are at moderate to high levels. Further he observed that the available N content at 0-15 and 15- 30 cm depth is 149.5 mg L<sup>-1</sup>, 143.0 respectively in upland sewage fed soils. On the other hand in the low land sewage fed soils the available N content at 0-15 cm, 15-30 cm depth is 217.0, 130.0 mg L<sup>-1</sup> respectively. In both the cases the available N content decreased with depth.

### Available Phosphorus

Available P content in 0-15 cm, 15-30, 30-60 and 60-120 cm soil layers were more in the sewage fed soils by 20, 15, 10 and 7 mg L<sup>-1</sup> phosphorus respectively. Maximum accumulation of N, P occurred with in 0-60 cm soil layer below this depth the increase in these contents was not remarkable.

Available phosphorus in sewage fed soils around Budha Nallah, Ludhiana ranged between 17 to 66 mg L<sup>-1</sup> and 9.2 to 41 mg L<sup>-1</sup> respectively in surface layers of soils supplemented with and without sewage waste waters for irrigation purpose, whereas its content decreased with depth under both the situations. The available P was in the range of high to very high for sewage fed soils and medium to high in soils where no sewage water was applied. The high content of P in the sewage fed soils may be attributed to the use of fact that considerable P is present in the domestic sewage due to the use of detergents for washing (Azad *et al.*, 1987).

Maiti *et al.* (1992) observed that the available P content of sewage fed soils of Calcutta city are at moderate to high levels. On the otherhand, the available P contents of at 0-15, 15-30 cm depth are 56.2, 41.5 mg L<sup>-1</sup> for upland soil and 51.2 and 31.7 mg L<sup>-1</sup> for lowland soils. The available P content decreased with depth in both upland and lowland soil.

### Available Potassium

Azad *et al.* (1987) in his irrigation experiments with sewage water at Ludhiana, Punjab reported that the total K content increased with depth

and it varied from 1.13 to 3.83 per cent and 1.15 to 5.65 per cent in the surface and sub surface layers of sewage fed soils. When compared with normally irrigated soils significantly higher amount of total K were observed in 0-15 and 0-30 cm soil layers of sewage treated soils. Generally the subsoil layers contained higher amount of total-K in comparison to the surface layer.

Available K content of sewage fed soils of Calcutta city is at moderate to high levels. The available K at 0-15, 15-30 cm is 165, 240 mg L<sup>-1</sup> in upland soils and 190, 230 mg L<sup>-1</sup> low land. Available K content increased with depth (Maiti *et al.*, 1992).

### Chlorides and Sulphates

Lal Kansal *et al.* (1993) collected soil samples from irrigated land irrigated by water of Hakimwala drain, Amritsar and reported that the Cl<sup>-</sup> and S<sub>4</sub><sup>2-</sup> in soil irrigated by Halum Waldrain are 400 and 160 ug/gm respectively and the corresponding Cl<sup>-</sup> and S<sub>4</sub><sup>2-</sup> in same soils irrigated with tube well water are 180 and 240 mg kg<sup>-1</sup> respectively.

### MICRONUTRIENTS

Environmental pollution is increasing due to urbanisation and industrialization. The disposal of city waste, sewage water and industrial effluents is becoming a major problem. The raw sewage waters contain beneficial as well as toxic elements. Longterm use of these waters for irrigating crops may cause micronutrient and heavy metal accumulation in soils to such an extent that they may be phytotoxic to plants.

Kuhad *et al.* (1989) has conducted a study on the mobility and accumulation of heavy metals in sewage irrigated soils in Haryana and reported that the total Zn, Cu, Mn, Fe in the soils ranged from 13.3-22.96, 55.0 -2500, 119.0-22.8 and 21250-97500 mg L<sup>-1</sup> respectively. Maximum accumulation of these metals was observed in AP horizon of Sonapat profiles. He attributed that higher accumulation of metals in surface layer of Sonapat Soil, may be due to continuous irrigation of soil by the sewage water charged with metal rich cycle industry effluents.

Azad (1994) has conducted a study in areas around open sewage canal passing through Ludhiana, Punjab to know the fate of iron in sewage waste water irrigated soils and reported that total Fe content varied from 1.4 to 3.2 per cent in 0-15 cm layer of normal soils with a mean value of 2.03 per cent whereas in soils receiving sewage waste water, total iron ranged from 2.2 to 4.1 per cent higher than in the normal soils. These values are well with in the range of 0.4 to 27.3 per cent iron in normal soils of India. The correlation studies indicated that total Fe accumulation in the surface layer (0-15 cm) was significantly correlated with CaCO<sub>3</sub>, whereas at 0-30 cm soil layer the total Iron was negatively correlated with pH, CaCO<sub>3</sub> and sand irrespective of the fact whether the soil received sewage water or not. EC contributed significantly and positively only in case of sewage fed soils. The studies further reveal that the total Fe accumulation was 75 and 64 per cent in normal and sewage fed soils respectively.

Singh *et al.* (1994) in the fields around Varanasi, U.P observed that the surface layer of the three profiles, Mn 225.62 <sup>contained</sup> and Cu 30.26 to

30.70, Zinc 15.52 to 15.58 and Fe 232.24  $\text{mg kg}^{-1}$  on the other hand in lower most horizons the metal contents ranged from 8.08 to 12.44, 4.32 to 10.02 and 204.01 to 213.20 and 68.16 to 86.42  $\text{mg L}^{-1}$  which may be due to reduced mobility of metals into lower horizons. Specific absorption of heavy metals by organic matter, manganese oxides, Iron oxides, clay minerals, humic acid, fulvic acids possibly have restricted their mobility to the deeper horizons.

### Zinc

Misra and Dinesh Mani (1993) in a study undertaken at Sheela Dhar Institute experimental farm have reported that there was no much variation in total zinc in sewage irrigated and non sewage irrigated soils samples. But exchangeable zinc in sewage irrigated soil is always more than 3 times that of non-sewage irrigated soils. They have inferred that increased level of available zinc may be due to sewage irrigation alone. The total zinc in sewage soil (108 to 185  $\text{mg kg}^{-1}$ ). They further observed that eventhough total zinc showed variable distribution pattern but DTPA Zn always decreases with increase in soil depth.

### DTPA extractable micronutrients

Kuhad *et al.* (1989) has conducted a study on mobility and accumulation of heavy metals in sewage irrigated soils in Haryana and reported that DTPA extractable Zn, Cu, Mn and Fe ranged from 0.28 - 89.3, 1.2 - 15.0, 1.98 - 7.46 and 2.87 - 2.92  $\text{mg L}^{-1}$  respectively. He observed that available micronutrients decreased with increase in depth and that maximum accumulation

of micronutrients was observed in the surface horizons of all soils. Further observed that available Mo increased with depth in all the profiles except in Ali Soil where a reverse trend was observed. The higher content of Mo in Panipat and Sompet may be due to higher pH values.

Azad(1994)in a study conducted at Ludhiana, Punjab to know the fate of Iron in sewage water irrigated soils reported that the DTPA Fe content in the depth of 0-15 cm was 5.8 to 24.4 mg L<sup>-1</sup> and 11.1 to 39.4 mg L<sup>-1</sup> for normal and sewage waste water irrigated soils respectively. The corresponding increase in DTPA Fe in the later case was 77 per cent and the average values for DTPA Fe were 14.1 and 29.9 mg L<sup>-1</sup> under the two situations respectively. Higher contents of total and DTPA Fe in top 0-15 cm soil layer may be due to application of sewage water. Cumulation Studies of 0-30 cm soil layer revealed that DTPA Fe content was significantly and positively correlated with EC, organic matter, clay and silt and significantly negatively correlated with pH and sand irrespective of soil types, whereas CaCO<sub>3</sub> contributed significant and negatively towards DTPA-Fe accumulation in normal soils.

Jayabhaskaran and Sreeramulu (1996) have conducted a study on distribution of heavy metals in soils of various sewage farm in Tamil Nadu and reported that DTPA extractable Fe, Cu, Mn, Zn contents of soils of different sewage farms decreased with different degrees of increasing distance from the sewage entry point. They further observed that DTPA extractable Fe, Cu, Mn, Zn accumulated more at the surface depths and decreased thereafter significantly. The soils of Udakkam upto 0-30 cm registered higher

heavy metal contents. This may be due to lower permeability of Udakkam soil vertical mobility. The restriction to downward mobility of metals of Udakkam soils is due to the clayey nature of Udakkam soils indicating that soil texture plays a major role in vertical mobility of the metals in the soils. Significant positive correlations between organic carbon content and DTPA extractable metal contents of soils of different sewage farms were found. The correlation between soil organic carbon content and DTPA extractable metal contents were in the order  $Mn > Cu > Fe > Zn > Co > Cr > Cd > Pb > Ni$  which indicates that most of the extractable metals were in chelated form.

### Heavy Metals

Increasing use of sewage containing domestic and industrial wastes on soils of sewage farms is a common practice in several places. Nevertheless higher concentrations of trace metals on land receiving the sewage are of public concern because of possible phytotoxicity or increased movement of metals into the food chain (Heckman *et al.*, 1987). Pollution of surface and ground water is also hazardous. To minimize the threat of land and ground water contamination, accurate estimation of vertical and horizontal movement of heavy metals is important.

### Heavy Metals -

Anderson (1976) and Lutrele *et al.* (1976) also observed increase in Cd and Ni contents in the soils due to continuous application of sludge and liquid sludge.

Azad *et al.* (1986) conducted field studies in cultivated lands around Ludhiana city and reported that the contents of total Cd, Ni and Co in the surface layers of normal soils (i.e. not irrigated with sewage water) ranged from 0.53 to 1.05 mg kg<sup>-1</sup>, 18.0 to 30.0 mg kg<sup>-1</sup> and 11.0 to 21.0 mg kg<sup>-1</sup>, respectively, whereas the corresponding values for sewage treated soils were 0.83 to 1.58 mg kg<sup>-1</sup>, 3.50 to 65.0 mg kg<sup>-1</sup> and 16.0 to 31.0 mg kg<sup>-1</sup>, respectively. The mean values of Cd, Ni and Co were 0.8 mg kg<sup>-1</sup>, 23.6 mg kg<sup>-1</sup> and 16.3 mg kg<sup>-1</sup> for untreated soils and 1.1 mg kg<sup>-1</sup>, 43.9 mg kg<sup>-1</sup> and 24.1 mg kg<sup>-1</sup>, respectively for the sewage irrigated soils. Thus the increase in total Cd, Ni and Co content due to sewage water addition may be 36.0, 86.4 and 46.4 per cent. Irrespective of the sewage application, the total Cd content decreased with depth. Average content of Cd in normal and sewage treated soils at 0-15, 15-30, 30-60 and 60-120 cm depth was 0.62 and 1.09; 0.62 and 0.93; 0.49 and 0.73; and 0.33 and 0.59 mg kg<sup>-1</sup> respectively. Total Ni content decreased with depth in the soil profile from 24.57 to 7.05 mg kg<sup>-1</sup>; and 4.338 to 14.14 mg kg<sup>-1</sup> in 0-120 cm depth of normal soils and those treated with sewage wastes, respectively. Nickel content of 15-30 cm and 30-60 cm depth was 15.71 and 12.60 mg kg<sup>-1</sup> in the soils irrigated with tubewell water and 34.29 and 23.86 mg kg<sup>-1</sup> in the soils irrigated with sewage waste water. Nickel was mainly concentrated upto 30 cm depth. The mean cobalt content was 23.4, 20.3, 17.1 and 13.2 mg kg<sup>-1</sup>, respectively at 0-15, 15-30, 30-60 and 60-120 cm depth in soils received sewage water. And for normal soils, the corresponding depth wise content of cobalt was 15.9, 12.8, 9.7 and 6.9 mg kg<sup>-1</sup>. The difference in the cobalt contents of each depth under the two situations was 7.5, 7.5, 7.4 and 6.3 mg kg<sup>-1</sup>, respectively, which

obviously reveals the build up of cobalt throughout the profile due to the sewage waste water application. The results of correlation studies have shown that the accumulation of Cd, Ni and Co was generally positively associated with EC, organic matter, silt and clay but negatively with pH,  $\text{CaCO}_3$  and sand.

Kuhad *et al.* (1989) studied mobility and accumulation of heavy metals in agricultural soil profiles at Ali, Sharam, Panipat and Sonapat receiving sewage water irrigation and reported that the total Cd, Pb, Ni, Co in the soils ranged from 0.15 - 2.5, 12.5 - 225, 20-4750 and 13.8 - 29  $\text{mg kg}^{-1}$  respectively. Maximum accumulation of all the metals except Co was observed in the  $A_p$  horizon of Sonapat profile, this may be attributed to the continuous irrigation of soil with the sewage water charged with metal rich cycle industry effluents. All the metals except Co decreased with increase in depth in Sonapat profile.

Misra and Dinesh Moong (1993) studied the distribution of heavy metals in the soils of SDI (Sheela Dhar Institute) experimental farm of Allahabad receiving sewage irrigation and it observed that the total Cd in sewage irrigated soils was always higher than non-sewage irrigated soils. The total Cd in different soils irrigated with sewage water ranged from 1.4 to 6  $\text{mg kg}^{-1}$ , against 0.55 to 1.7  $\text{mg kg}^{-1}$  in non sewage irrigated soils. On the other hand total Cr concentration in all the soil samples irrigated with sewage water is much higher than the non-sewage irrigated soils. The total Cr content decreased with depth from 9.8 to 2.4  $\text{mg kg}^{-1}$ , and 1.2 to 0.5  $\text{mg kg}^{-1}$  in 0 to 40 cm depth in sewage irrigated soil and in normal

soil respectively. They also reported that total Pb concentration in almost all soil samples irrigated with sewage water is much higher than non-sewage irrigated soil. Total Pb content decreased with depth from 4.6 to 1.4 mg kg<sup>-1</sup> and 1.0 to 0.38 mg kg<sup>-1</sup> in 0-4.0 cm depth in sewage irrigated soil and in normal soil, respectively.

Bhup. al Raj *et al.* (1997) reported that total heavy metal contents observed in surface soils (0-30 cm) were several times higher than the normal contents. The total heavy metal contents in a polluted soils were Pb 177.9; chromium 44.1; Nickel 32.8; Cadmium 4.2; Cobalt 36 per cent.

### 2.3 ACCUMULATION OF MICRONUTRIENTS AND HEAVY METALS IN PLANTS DUE TO SEWAGE IRRIGATION

Disposal of municipal wastes on agricultural land adds, metallic cations to the soil. Prolonged application of these materials to agricultural land resulted in accumulation of heavy metals in the rooting zone (Page, 1974). Because of this, metal toxicity may occur to plants and ultimately contamination of food chain. Some of these elements are useful in low concentration, but inhibitory in high concentrations, whereas others have an overall toxicity effect on plants.

The normal values in ppm for heavy metals found in rice at the age of 30-45 days after transplantation were as Zn: 10; Cu : 40; Fe : 60; Mn: 50; Pb 2; Cr: 1; Ni : 1; Cd 0.5 and Co 0.1 (APAU 1967-95).

### 2.3.1 Accumulation of micronutrients in plants

#### Iron

Adhikari *et al.* (1993) reported that sewage water irrigation in vegetable crops (gourd, mustard, spinach, cauliflower, radish) resulted in exceptionally high concentration of Fe in different parts.

Narwal *et al.* (1994) observed that application of Ni significantly increased the tissue Fe concentration of corn at all levels of Zn. Application of Zn resulted in increase in tissue Fe concentration of corn.

Misra and Pawan Kumar (1993) reported that higher doses of sewage treatment recorded higher available Fe, this resulted in reduced growth and biomass of fenugreek owing to higher heavy metal concentration but when coupled with Missouri Rock Phosphate (MRP) it resulted in positive increase of Biomass. This is due to phosphate MRP becomes available and forms complexes with the added heavy metals there by decreasing the availability of heavy metals especially Fe.

#### Copper

King *et al.* (1974) reported that yields of corn 188 mt ha<sup>-1</sup>, however the level of Cu increased in rye and corn plants by increased sewage addition but were below toxic levels to crop.

Kelling *et al.* (1977) reported that addition of sludge increased the concentrations of Cu, Zn, Cd and Ni in vegetative tissue except for Zn, the additions had relatively little effect on metal content in corn grain.

Chromium did not accumulate in the leaf tissues or grain. In all the cases concentrations of metals were below <sup>toxic</sup> levels to crops.

King *et al.* (1977) state that there was no effect of sewage treatment on Cu levels in the corn grain whereas only Cu levels in the straw were increased each year.

Adhikari *et al.* (1993) reported that exceptionally high concentration of Cu was found in different parts of vegetables (viz., gourd, mustard, spinach, cauliflower, radish) when irrigated with sewage water.

Narwal *et al.* (1994) reported that Ni application resulted in decrease in Cu concentration of corn. This antagonist behaviour of Ni may be due to the fact that both Ni and Cu cations might decrease those availability by competing at exchange sites in the soil and on plant roots.

Misra and Pawan Kumar (1993) observed that higher drop of sewage is ( $45 \text{ t ha}^{-1}$ ) recorded higher available Cu ( $3.56 \text{ mg L}^{-1}$ ). The available Cu content on soil decreased from 3.5 to  $2.75 \text{ mg L}^{-1}$  by applying different doses of MRP.

The copper content found in plants (paragrass) was 9.1 ppm which was several times more than normal, in plants receiving sewage water irrigation (Bhupal Raj *et al.*, 1997).

### Zinc

Singh and Sukhla (1985) reported that response to Zn was not observed above the critical limit for corn ( $0.8 \text{ mg kg}^{-1}$ ).

Reddy *et al.* (1989) reported that soybean treated with sewage irrigation resulted in lower concentration of Zn in seed than in other tissues (leaf and stem). He also reported that application of Zn upto 25 mg kg<sup>-1</sup> did not influence the tissue Ni concentration of corn. Further increase in Zn application increased the Ni concentration significantly.

Narwal *et al.* (1994) reported that Zn concentration of corn decreased due to application of Ni. However Zn concentration was higher at the highest rate of Zn and Ni (100 mg kg<sup>-1</sup>) when compared to their preceding levels. This was due to the concentration effect caused by the sharp decrease in corn yield.

The Zn content found in plants (paragrass) grown on soils along the Musi river around Hyderabad irrigated with domestic sewage was 71.9 ppm which is several times higher than the normal (Bhupal Raj *et al.*, 1997).

### **Manganese**

Narwal *et al.* (1994) reported that Mn content increased with increasing levels of Ni and Zn, tissue Mn concentration increased by about 1.6 and 1.8 times with the application of highest levels of Ni and Zn (100 mg kg<sup>-1</sup>).

Misra and Pawan Kumar (1993) reported that higher doses of sewage treatment recorded higher available manganese.

Bhupal Raj *et al.* (1997) reported that in the plants (Paragrass) grown on soils along the Musi river around Hyderabad, the Mn content was 51.4 ppm which is above the normal.

### 2.3.2 Heavy metals accumulation in plants due to sewage irrigation

#### Nickel

Patel *et al.* (1976) reported that a non-significant interaction between Ni and Zn.

King *et al.* (1977) stated that there was no effect of sewage treatments on Ni levels in the corn grain or straw.

Narwal *et al.* (1994) in a green house experiment conducted on corn grown on a typical ustipsamment soil treated with sewage water reported that interaction effect of Ni and Zn was observed only at that highest application rates and was antagonistic. Zn and Ni acted independently of each other in relation to phytotoxic effects on the crop and only interacted when one or the other element approached a hyper critical level. He also reported that application of Ni increased the tissue Ni concentration of corn significantly, Ni concentration increased by about 12 times with the application of highest level of Ni ( $100 \text{ mg kg}^{-1}$  soil). The application of  $400 \text{ mg kg}^{-1}$  Ni killed corn plants grown in sandy soil. Plant Ni content increased with increasing Ni rate.

## Cadmium

Kirkham (1975) analysed corn plants growing on a sludge disposal farm at Dayton Ohio and reported that soil cadmium increased from 2 to 70 ppm and cadmium in corn leaves increased from 2.1 to 14 ppm but in corn grain increased only from 0.8 to 1.0 ppm in sludge treated and supernatant treated areas as compared to cadmium concentration in soil.

Chaney *et al.* (1973) reported no increase in cadmium in pasture grasses even after 24 years of treatment with low cadmium waste water.

Jones *et al.* (1975) reported that plant cadmium levels increase with waste water application in corn.

Narwal *et al.* (1995) reported that dry matter yield of maize decreased significantly with increasing cadmium content of the water.

## Lead

Adhikari *et al.* (1993) reported that sewage water irrigation for vegetable crops (gourd mustard, spinach, cauliflower, radish) resulted in accumulation of lead above the critical limit in different parts.

## Chromium

In plants grown along the Musi river around Hyderabad, which are irrigated with sewage and industrial effluent water the chromium content ranged between 2.8-12.2 ppm with a mean value of 4.81 ppm, which is 4.8 times high when compared to normal chromium content in paragrass (Bhupal Raj *et al.*, 1997).

## Cobalt

In general, legumes, cereal forages and most weeds are high in cobalt content but grasses are relatively low in cobalt (Allaway, 1968).

Mean plant accumulation of cobalt varied from species to species (Lyon *et al.*, 1971).

Bhupal Raj *et al.* (1997) reported that in plants (Paragrass) receiving sewage and industrial effluent water irrigation the cobalt content ranged from 6.5-11.6 with a mean of 8.58 ppm. The percentage of samples falling under excess/toxic category is 100.

From the above review it is evident that rapid urbanisation experienced world wide has caused pollution of environment through the vast quantities of waste generated. It is necessary to evaluate effect of disposal of sewage on agricultural land.

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***MATERIALS AND METHODS***

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## CHAPTER III

# MATERIAL AND METHODS

### 3.1 INTRODUCTION

Use of sewage water with or without treatments is most widely practical method in areas adjoining sewage canals in several Indian cities including Hyderabad. Sewage irrigation may result in the accumulation of heavy metals and soluble salts in soils to such a level that may become phytotoxic and eventually be hazardous to animals and human health after entering the heavy metals in their systems through food chain. The methodology employed and materials used in the studies conducted to evaluate the impact of long term sewage irrigation on soil properties and uptake of heavy metals by maize plant are detailed hereunder.

### 3.2 STUDY AREA

Maize Research Station, is located at Amberpet, Hyderabad. It was established in an area of 127 ha in 1953 and was recognised under All India Co-ordinated Maize improvement Project in 1957 by ICAR.

About 250 million litres sewage is produced daily in Hyderabad city (Hyderabad Municipal Waste water and Sewage Board, Amberpet).

Raw sewage water from the city sewage canal is being used for irrigating maize crop in the Maize Research Station since its establishment (1953) i.e., from last 45 years. Irrigation channels have been laid with

cement, all through the farm. The channels have been designed in such a way that sewage water passes, to each and every plot of the sewage farm.

### 3.3 COLLECTION OF SAMPLES

Sewage water samples from Municipal sewage canal at Amberpet, Hyderabad were collected from 3 points in duplicate at 15 days interval for three months and analysed following the Standard methods for examination of Waters and Waste Waters (APHA,1985) and mean values were reported.

Details of the sewage waters collected are presented in Table 1.

**Table 1 : Details of Sewage Waters Collected**

Sewage Water Sample No.	Details of Sewage Water
1.	Collected from the main canal
2.	Collected from the inlet Channel in the farm
3.	Collected from Sub Channel in the farm

#### 3.3.1 Method of collection of Sewage Water Samples



Stoppered polythene bottles of two litres capacity were used for collecting sewage water samples. Each bottle was thoroughly washed with diluted HCl and then was rinsed with distilled water. The Dissolved Oxygen, pH and EC were measured immediately and samples were stored at 4<sup>o</sup>c until further use. For physico-chemical analysis (APHA, 1983). Details of the standard methods used for Waste Water analysis are given in Table 2.



Table 2: Methods used for Sewage Water Analysis (APHA, 1985)

S.No.	Test conducted	Unit	Principle of the method	Reference
1.	Electrical conductivity	dSm <sup>-1</sup>	Digital conductivity bridge	American Public Health Association, for the examination of water and waste water, 1985
2.	Total Solids	mg L <sup>-1</sup>	Evaporation	-do-
3.	Total dissolved and suspended solids	mg L <sup>-1</sup>	Filtration and Evaporation	-do-
4.	pH	-	Digital pH meter	-do-
5.	Biochemical Oxygen Demand (BOD)	mg L <sup>-1</sup>	Sample measured at 5 days at 20°C	-do-
6.	Chemical Oxygen Demand (COD)	mg L <sup>-1</sup>	Organic Substances are oxidized by K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> in H <sub>2</sub> SO <sub>4</sub> (1+1) at reflex temperature	-do-
7.	Dissolved Oxygen ((DO)	mg L <sup>-1</sup>	Winkler's Method	-do-
8.	Carbonates (CO <sub>3</sub> <sup>-2</sup> )	mg L <sup>-1</sup>	When P < 1/2 T = 2 P P = 1/2 T = 2P P = T = 0	-do-
9.	Bicarbonates (HCO <sub>3</sub> <sup>-</sup> )	mg L <sup>-1</sup>	When P < 1/2 T = T-2p P = 1/2 T = 0 P = T=0	-do-
10.	Chlorides (Cl <sup>-1</sup> )	mg L <sup>-1</sup>	Titration with Standard AgNO <sub>3</sub> using K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as indicator	-do-
11.	Sulphates (SO <sub>4</sub> <sup>-2</sup> )	mg L <sup>-1</sup>	Turbidimetric method using BaCl <sub>2</sub>	-do-
12.	Sodium and Potassium	mg L <sup>-1</sup>	Flame Photometer	-do-
13.	Phosphorus (PO <sub>4</sub> <sup>-2</sup> )	mg L <sup>-1</sup>	Colorimetric analysis using ascorbic method	-do-
14.	Total Nitrogen (Nitrates)	mg L <sup>-1</sup>	Phenol disulphonic acid	-do-
15.	Calcium and Magnesium	mg L <sup>-1</sup>	EDTA - titrimetric method	-do-
16.	Heavy metals (Cd, Pb, Ni, Cr, Co) and micronutrients (Fe, Zn, Cu, Mn)	mg L <sup>-1</sup>	HNO <sub>3</sub> digestion and atomic absorption spectro photometer	-do-

SCALE 1 INCH = 100 FEET

LEGEND

-  UNDER CULTIVATION
-  CULTURABLE WASTE

-  PROFILES
-  SURFACE SAMPLES
- P<sub>I</sub>, P<sub>II</sub>, P<sub>III</sub> - Sewage treated profile
- C<sub>I</sub>, C<sub>II</sub> - Control profile

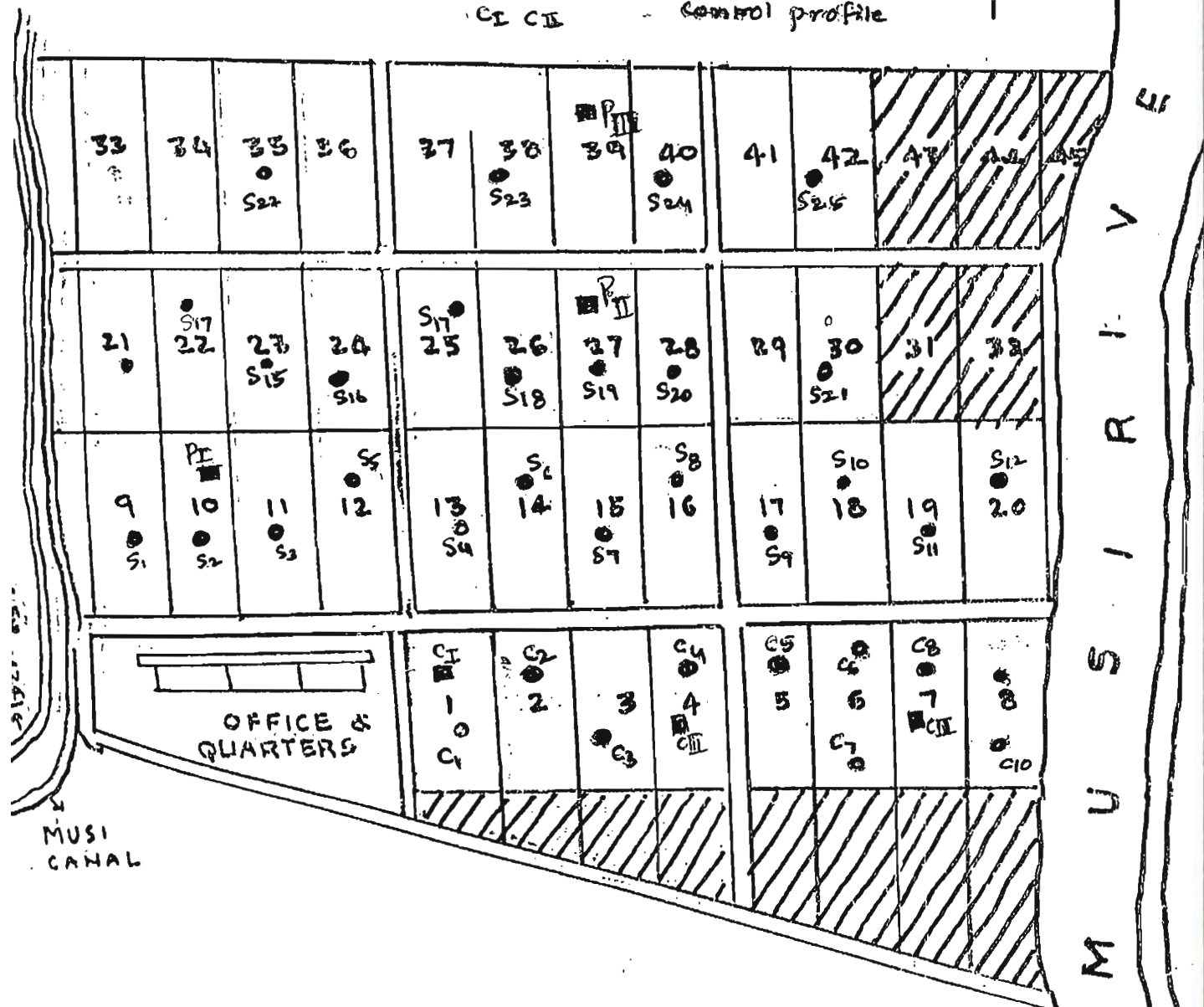
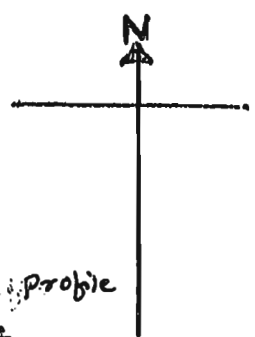


FIG 1 LAY OUT OF SEWAGE FARM AMBERPET

For heavy metal analysis, separate glass bottles were used for sampling. Water samples were acidified with 1.5 ml of  $\text{HNO}_3\text{L}^{-1}$  (APHA, 1985).

### 3.3.2 Collection of Soil Samples

To study the impact of continuous sewage water irrigation on soil chemical properties, surface and profile soil samples from Maize Research Station, Amberpet, Hyderabad were collected. Twenty five surface samples from different plots irrigated with sewage water were collected. Ten surface samples were also collected from different plots which are not being irrigated with sewage water as controls. Three soil profile samples from three locations in the sewage farm irrigated with sewage water were collected. Two soil profile samples were collected from untreated area of the sewage farm as controls. The soil profile samples were collected at 3 depths i.e. 0-15, 15-30 and 30-45 cm (Fig. 1).

The soil samples collected in cloth bags were dried under shade, pounded using a wooden pestle and mortar and passed through a 2 mm sieve and stored until further analysis.

The methods used for analysis of soil samples are given in table 3

3.

Table 3: Methods used for Soil Analysis

S.No.	Test conducted	Method	Reference
1.	Particle size	Hydrometer	Piper (1950)
2.	pH and EC	Soil and Water Suspension (1:2)	Jackson (1973)
3.	Organic Carbon	Chromic acid wet digestion (Walkley and Black) 1945	Jackson (1973)
4.	NH <sub>4</sub> OAc extractable Na and K	In 1N NH <sub>4</sub> OAc leachate-using flame photometer	Jackson (1973)
5.	Exchangeable Na and K	Obtained by deducting the Water Soluble Na and K from NH <sub>4</sub> OAc extractable Na and K	Page (1982)
6.	Exchangeable Ca and Mg	Sodium acetate method	Bowar <i>et al.</i> (1952)
7.	Available nitrogen	Alkaline Permanganate	Subbaiah and Asija (1956)
8.	Available phosphorus	Olsen's extractant (Sodium bicarbonate)	Olsen <i>et al.</i> (1954)
9.	Available potassium	1N NH <sub>4</sub> OAc method	Jackson (1973)
10.	Cation Exchange Capacity	Sodium acetate method of Bowret <i>et al.</i> (1952)	Richards <i>et al.</i> (1954)
11.	Water Soluble : Na and K Sulphate Chloride	Saturation extracts Flame Photometer BaCl <sub>2</sub> method AgNO <sub>3</sub> and K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> method	Richards <i>et al.</i> (1954)
12.	E.S.P.	$\frac{\text{Exch. Na (cmol (p+) kg}^{-1} \text{ Soil)}}{\text{CEC (c mol (p+) kg}^{-1} \text{ soil)}} \times 100$	Soil Science Society of America (1984)
13.	DTPA-extractable metals (Zn, Fe, Cu, Mn, Pb, Ni, Cr, Cd and Co)	DTPA + CaCl <sub>2</sub> + TEA with pH adjusted to 7.3± 0.05	Lindsay and Norvell (1978)
14.	Total metals (Zn, Mn, Cu, Fe, Cr, Cd, Pb, Ni and Co)	Diacid digestion Atomic absorption spectrophotometer	Sandell and Onishi (1978)
15.	Water soluble Na and K Sulphate Chloride	Saturation extracts Flame photometer, BaCl <sub>2</sub> method, AgNO <sub>3</sub> and K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> method	Richards (1954)
16.	Relative availability of metals (%)	$\frac{\text{Concentration of DTPA extractable metal}}{\text{Concentration of total metal}} \times 100$	

### 3.3.3 Collection of Plant Samples

Ten maize plant samples (stalk, grains) were collected from sewage irrigated plots at random and were analysed for micronutrient and heavy metals.

To determine the micronutrients and heavy metals content in plant in maize  $\text{HClO}_4$ , 1.0 g of the plant sample was digested with 10 ml of concentrated  $\text{HNO}_3$  and 3 ml of  $\text{HClO}_4$  for 3 hours (AOAC, 1980). The residue dissolved in 5 ml of 6N. HCl and was made up to 50 ml with double distilled water. The extracts for metals were analysed by using atomic absorption Spectrophotometer.

### 3.3.4 Statistical analysis

Statistical methods recommended by Gomez and Gomez (1984) were employed to process the data generated from Laboratory. The data of various characters were computerised and subjected to Statistical analysis. For comparing sewage irrigated and control soil samples, two sample 't' test has been used. For comparing sewage irrigated and control soil profiles at different depths two factorial Randomised block design (RBD) has been used.

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# *RESULTS*

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## CHAPTER IV

### RESULTS

The results pertaining to the present investigation on "Impact of sewage irrigation on soil chemical properties" are presented in this chapter.

#### 4.1 CHARACTERISTICS OF SEWAGE WATER COLLECTED FROM MAIZE RESEARCH STATION, AMBERPET, HYDERABAD

Physico-chemical and chemical characteristics of sewage water are presented in Table 4 and illustrated in Fig. 2 to 6.

##### 4.1.1 pH

The pH of sewage water collected from sewage canal, Maize Research Station, Amberpet ranged from 7.12 to 8.5 with a mean value of 7.73.

##### 4.1.2 Electrical Conductivity (EC)

The range of EC of sewage water collected at fortnightly intervals was from 2.58 to 4.07 dS m<sup>-1</sup> with a mean value of 3.31 dS m<sup>-1</sup>.

##### 4.1.3 Chemical Oxygen Demand (COD)

In the sewage water collected from Maize Research Station, Amberpet the COD ranged from 192 to 864 with a mean value of 545.33 mg L<sup>-1</sup>.

##### 4.1.4 Biological Oxygen Demand (BOD)

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The BOD of sewage water collected from Maize Research Station, Amberpet ranged from 80 to 278 with a mean value of 213.8 mg L<sup>-1</sup>.



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**Table 4: Physico-chemical, and chemical characteristics of sewage water collected from sewage canal at Maize Research Station, Amberpet, Hyderabad**

S. No.	Characteristics	Date of sampling						Range	Mean
		22nd Dec.	5th Jan.	19th Jan.	2nd Feb.	17th Feb.	9th March		
1	pH	7.4	7.12	8.5	8.04	7.90	7.44	7.12-8.5	7.73
2	E.C (dS m <sup>-1</sup> )	3.17	4.07	3.47	3.96	2.63	2.58	2.58-4.07	3.31
3	COD (mg L <sup>-1</sup> )	616	336	192	634	640	864	192-864	545.33
4	BOD (mg L <sup>-1</sup> )	275	120	80	260	270	278	278-800	213.8
5	DO (mg L <sup>-1</sup> )	3.93	4.04	3.72	4.20	4.68	4.40	3.72-4.68	4.16
6	T.S (mg L <sup>-1</sup> )	1844	2650	2152	2172	2184	2338	1844-2650	2223.3
7	T.D.S (mg L <sup>-1</sup> )	1636	2100	2047	1567	1588	1900	1567-2100	1806.3
8	T.S.S. (mg L <sup>-1</sup> )	208	550	105	605	596.6	438	105-605	417
9	Acidity (mg L <sup>-1</sup> )	106	76	56	112	90	174	56-174	102.33
10	Alkalinity (mg L <sup>-1</sup> )	664	912	488	586	588	406	406-912	607.3
11	Total N (mg L <sup>-1</sup> )	35.0	45.3	31.2	36.9	35.9	42.6	31.2-45.3	37.8
12	NO <sub>3</sub> N (mg L <sup>-1</sup> )	0.42	0.91	0.35	0.52	0.49	0.64	0.35-0.91	0.55
13	Phosphate (mg L <sup>-1</sup> )	5.56	6.52	10.43	5.60	4.50	8.76	4.5-10.43	6.84
14	Calcium (mg L <sup>-1</sup> )	152	128	160	132	124	124	124-160	136.66
15	Magnesium (mg L <sup>-1</sup> )	43.77	65.66	48.60	80.80	46.20	51.07	43.73-65.66	52.68
16	Potassium (mg L <sup>-1</sup> )	24.40	25.84	26.52	28.56	31.28	27.88	24.41-31.28	24.50
17	Sodium (mg L <sup>-1</sup> )	208.8	264.6	221.4	257.4	210.6	198.6	198.6-264.6	226.8
18	Chlorides (mg L <sup>-1</sup> )	823	118	723	1460	950	936	823-1460	1011
19	Sulphate (mg L <sup>-1</sup> )	475	525	415	883	285	270	270-883	475.5
20	Carbonates (mg L <sup>-1</sup> )	Traces	Traces	Traces	Traces	Traces	Traces		
21	Bicarbonates (mg L <sup>-1</sup> )	305.0	256.2	231.8	195.2	170.8	134.2	170.8-305.0	215.5
22	Zn (mg L <sup>-1</sup> )	0.346	0.341	0.234	0.353	0.274	0.330	0.234-0.353	0.313
23	Cu (mg L <sup>-1</sup> )	0.128	0.126	0.118	0.120	0.127	0.119	0.118-0.128	0.123
24	Fe (mg L <sup>-1</sup> )	2.2	4.8	4.3	2.7	6.1	3.1	2.2-6.1	3.86
25	Mn (mg L <sup>-1</sup> )	1.28	1.23	0.92	3.74	2.72	1.45	0.92-3.74	1.89
26	Pb (mg L <sup>-1</sup> )	0.057	0.060	0.058	0.068	0.10	0.058	0.057-0.10	0.07
27	Co (mg L <sup>-1</sup> )	0.121	0.018	0.019	0.017	0.033	0.012	0.012-0.121	0.036
28	Cr (mg L <sup>-1</sup> )	0.354	0.279	0.178	0.258	0.329	0.408	0.178-0.408	0.243
29	Cd (mg L <sup>-1</sup> )	0.024	0.025	0.029	0.027	0.026	0.032	0.024-0.032	0.027
30	Ni (mg L <sup>-1</sup> )	0.089	0.075	0.076	0.032	0.072	0.090	0.032-0.090	0.072
31	SAR	3.84	4.75	3.94	4.66	4.10	3.75	3.84-4.75	4.17

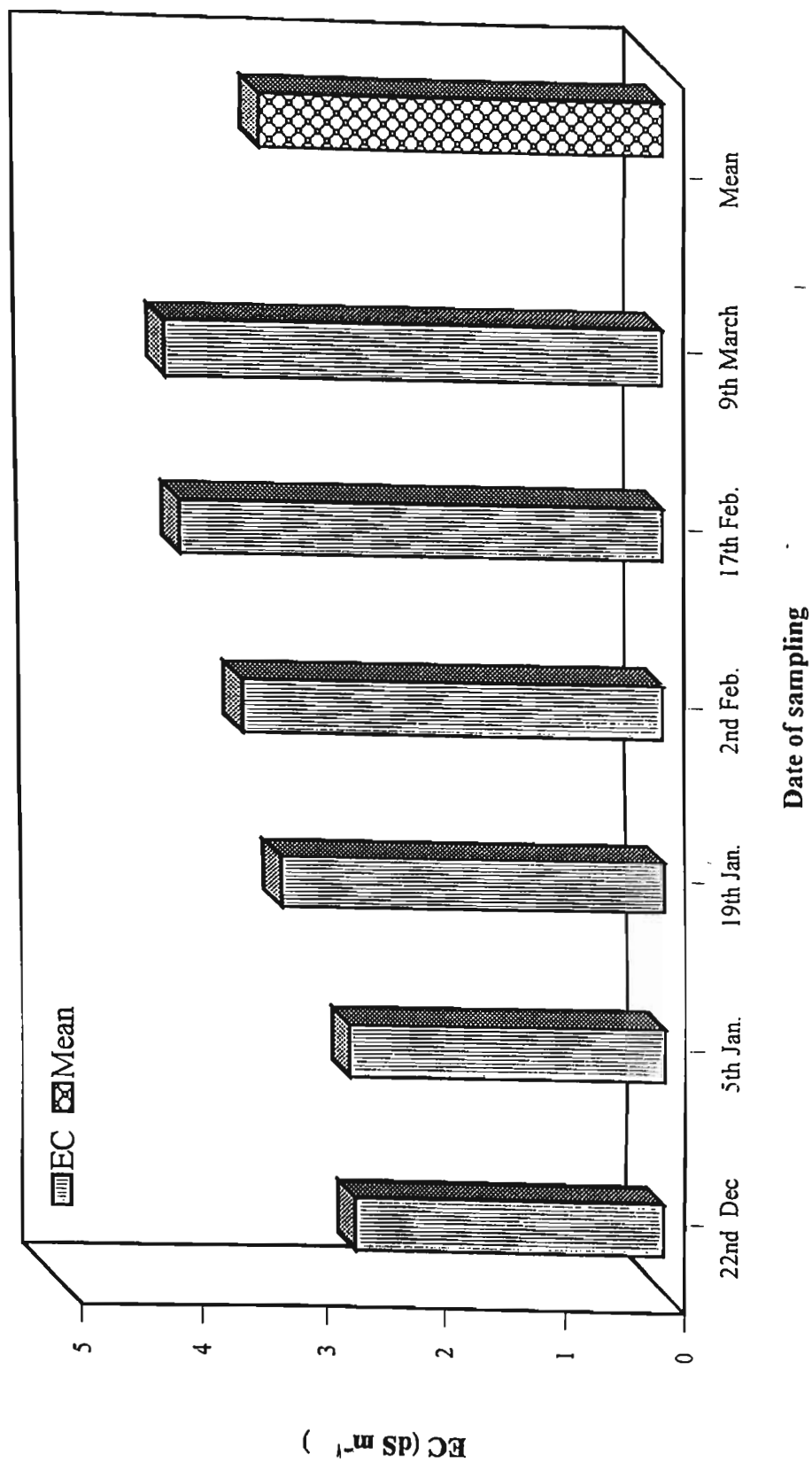
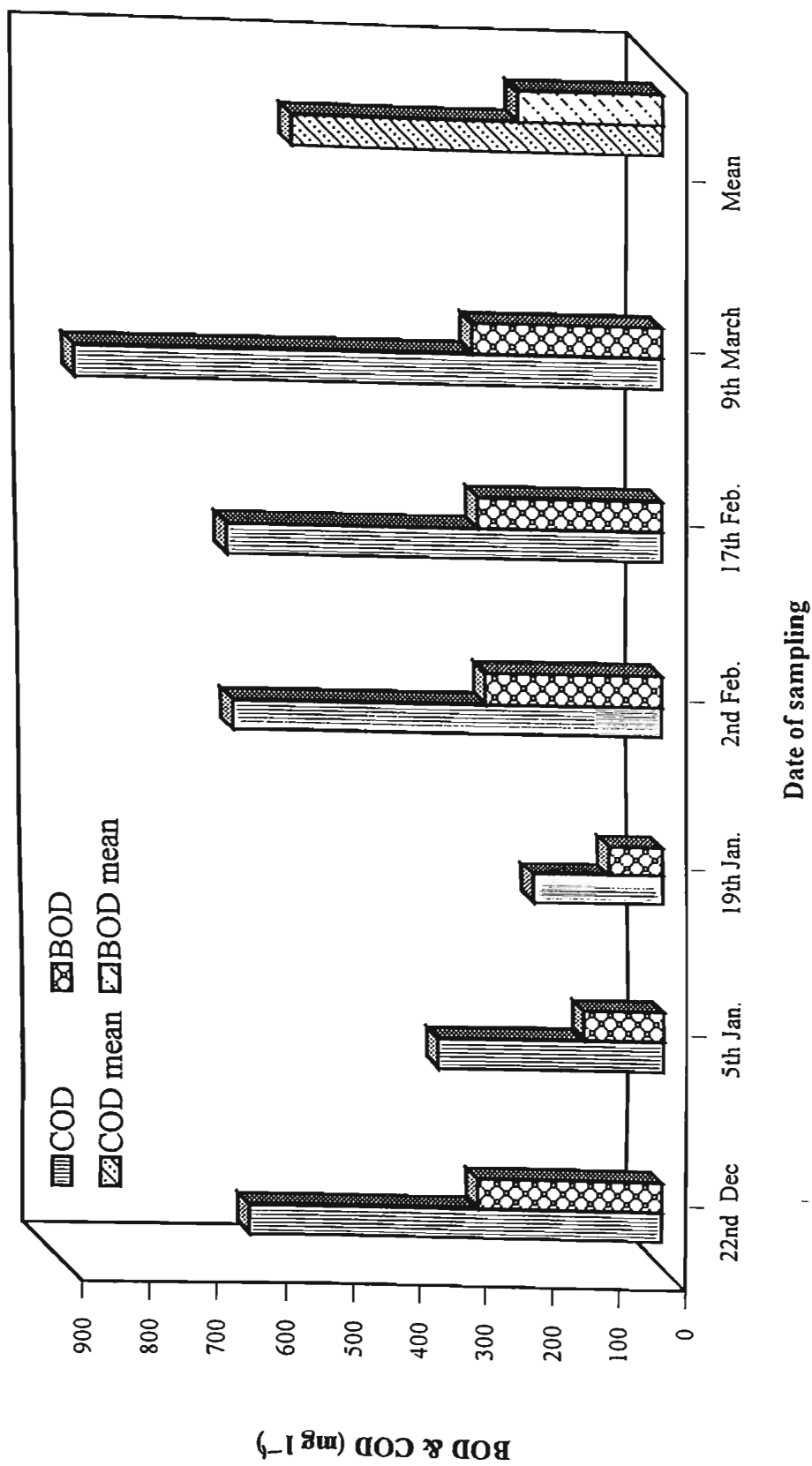


Fig. 2 : Electrical conductivity of sewage water at different dates of sampling  
(22nd Dec. 97 to 9th March 98)



**Fig. 3 : BOD and COD contents of sewage water at different dates of sampling (22nd Dec. 97 to 9th March 98)**

#### 4.1.5 Dissolved Oxygen (DO)

The DO of sewage water ranged from 3.72 to 4.68 mg L<sup>-1</sup> with a mean value of 4.16 mg L<sup>-1</sup>.

#### 4.1.6 Total solids (TS)

The total solids of sewage water ranged between 1844 to 2650 mg L<sup>-1</sup> with a mean value of 2223.3 mg L<sup>-1</sup>.

#### 4.1.7 Total Dissolved Solids (TDS)

The TDS of sewage water ranged from 1567 to 2100 mg L<sup>-1</sup> with the mean value of 1806.3 mg L<sup>-1</sup>.

#### 4.1.8 Total suspended solids (TSS)

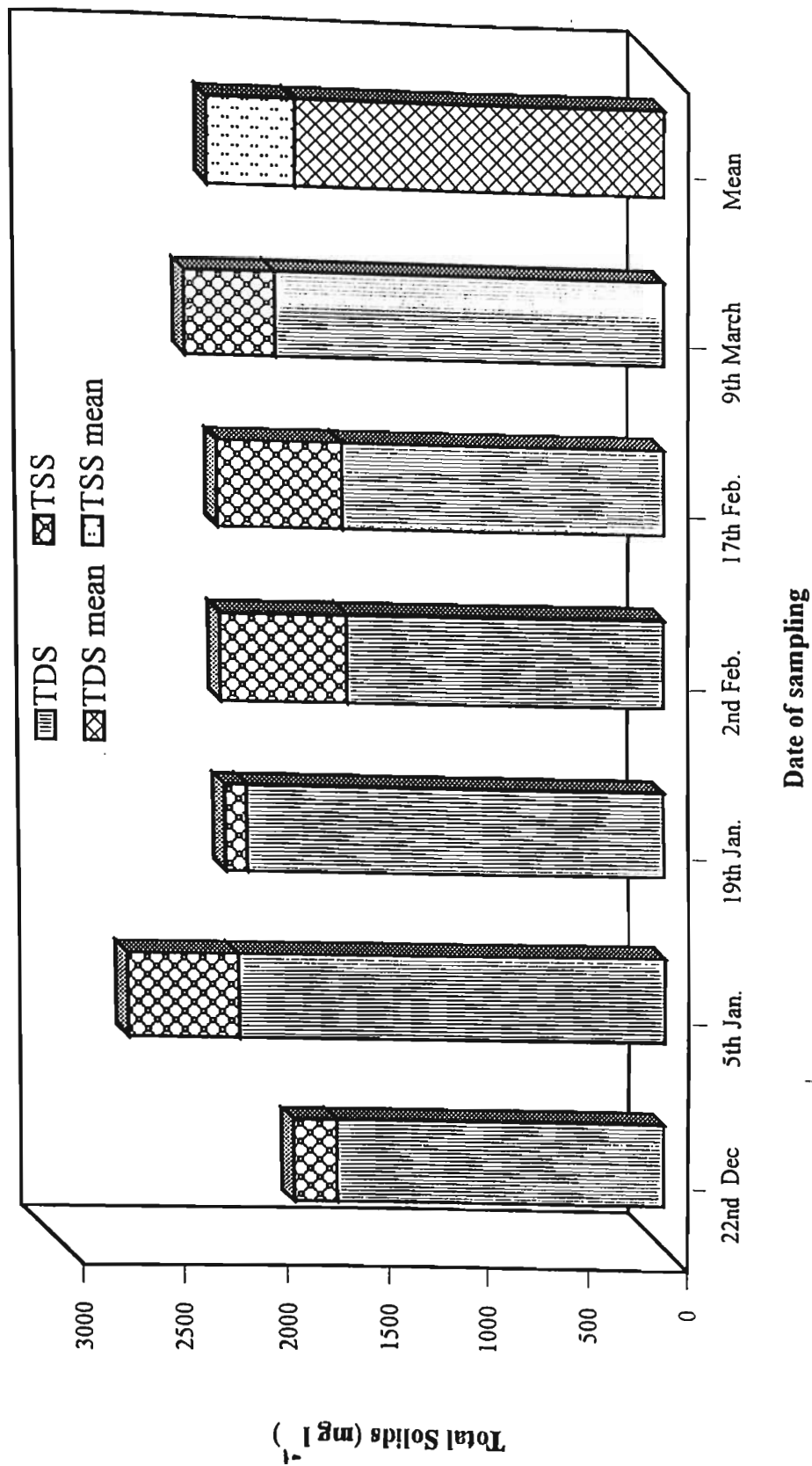
The TSS of sewage water ranged from 105 to 605 mg L<sup>-1</sup> with the mean value of 417 mg L<sup>-1</sup>.

#### 4.1.9 Acidity

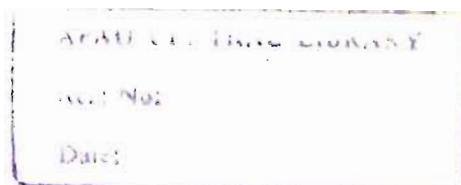
The acidity of sewage water ranged from 56 to 174 mg L<sup>-1</sup> and the mean value was 102.33 mg L<sup>-1</sup>.

#### 4.1.10 Alkalinity

The Alkalinity of sewage water ranged from 406-912 mg L<sup>-1</sup> and the mean value was 607.3 mg L<sup>-1</sup>.



**Fig. 4 : Total solids content of sewage water at different dates of sampling (22nd Dec. 97 to 9th March 98)**



#### **4.1.11 Total Nitrogen (Total N)**

The total N of sewage water ranged from 31.2 to 45.3 mg L<sup>-1</sup> with the mean value of 37.8 mg L<sup>-1</sup>.

#### **4.1.12 Nitrate nitrogen (NO<sub>3</sub>-N)**

The NO<sub>3</sub>-N of sewage water ranged from 0.35 to 0.91 mg L<sup>-1</sup> with the mean value of 0.55 mg L<sup>-1</sup>.

#### **4.1.13 Phosphate (PO<sub>4</sub><sup>-</sup>)**

The range of phosphate content of sewage water was between 4.50 and 10.43 mg L<sup>-1</sup> with the mean value of 6.84 mg L<sup>-1</sup>.

#### **4.1.14 Calcium (Ca)**

The Ca content of sewage water collected from sewage canal ranged from 120 to 160 with the mean value of 136.66 mg L<sup>-1</sup>.

#### **4.1.15 Magnesium (Mg)**

The Mg content of sewage water ranged from 43.73 to 65.66 mg L<sup>-1</sup> with the mean value of 52.68 mg L<sup>-1</sup>.

#### **4.1.16 Potassium (K)**

The K content of sewage water ranged between 24.41 and 31.28 mg L<sup>-1</sup> with the mean value of 24.50 mg L<sup>-1</sup>.

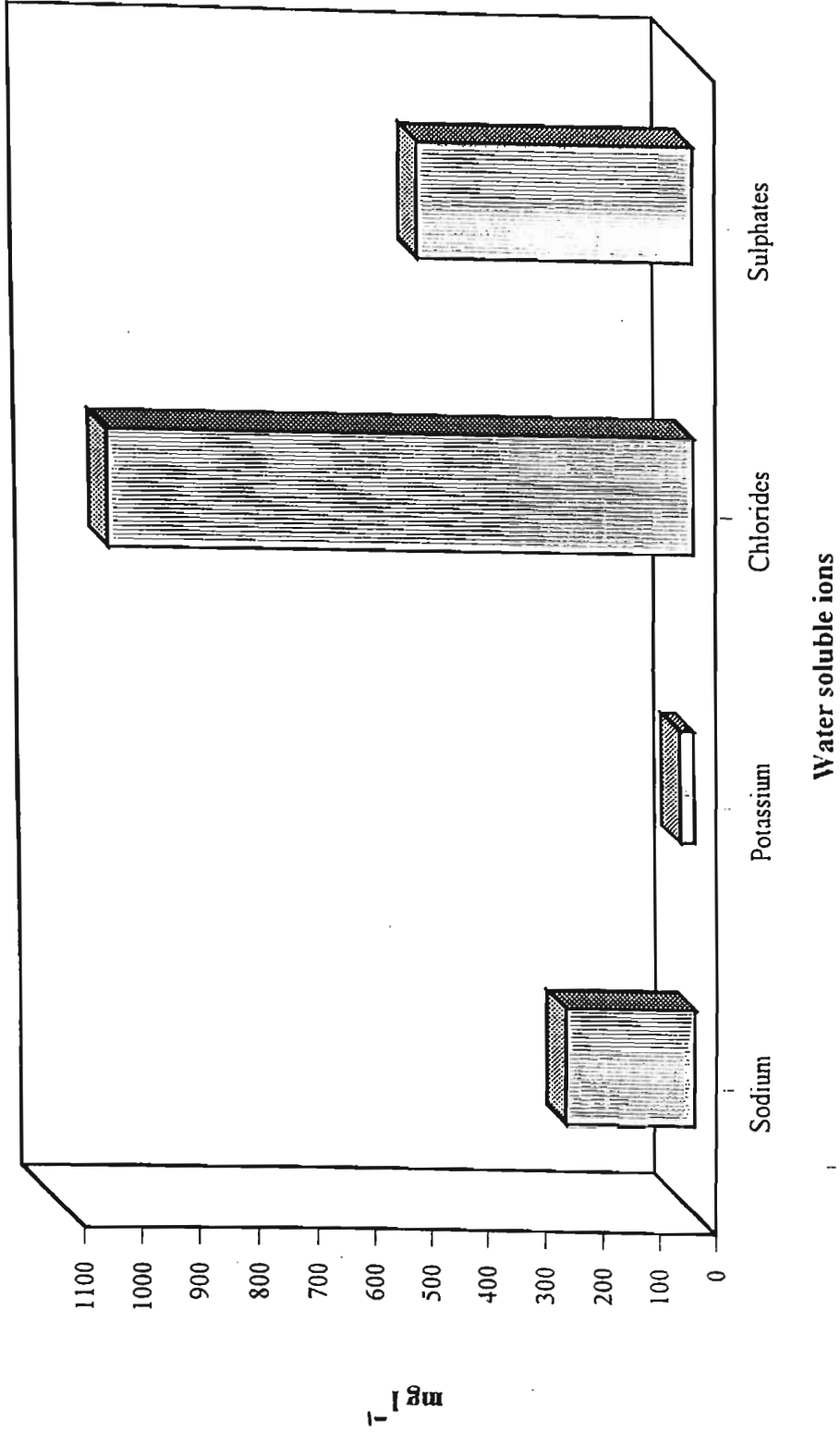


Fig. 6 : Sodium, potassium, chlorides and sulphates of sewage water

#### 4.1.17 Sodium (Na)

The Na content of sewage water ranged from 198.6 to 264.6 with the mean value of 226.8 mg L<sup>-1</sup>.

#### 4.1.18 Chlorides (Cl<sup>-</sup>)

The chloride content of sewage water ranged from 823 to 1460 with the mean value of 1011 mg L<sup>-1</sup>.

#### 4.1.19 Sulphates (SO<sub>4</sub><sup>-2</sup>)

The concentration of sulphates of sewage water ranged from 270 to 883 mg L<sup>-1</sup> with the mean value of 475.5 mg L<sup>-1</sup>.

#### 4.1.20 Carbonates (CO<sub>3</sub><sup>-2</sup>)

The concentration of carbonates of sewage water was in traces.

#### 4.1.21 Bicarbonates (HCO<sub>3</sub><sup>-</sup>)

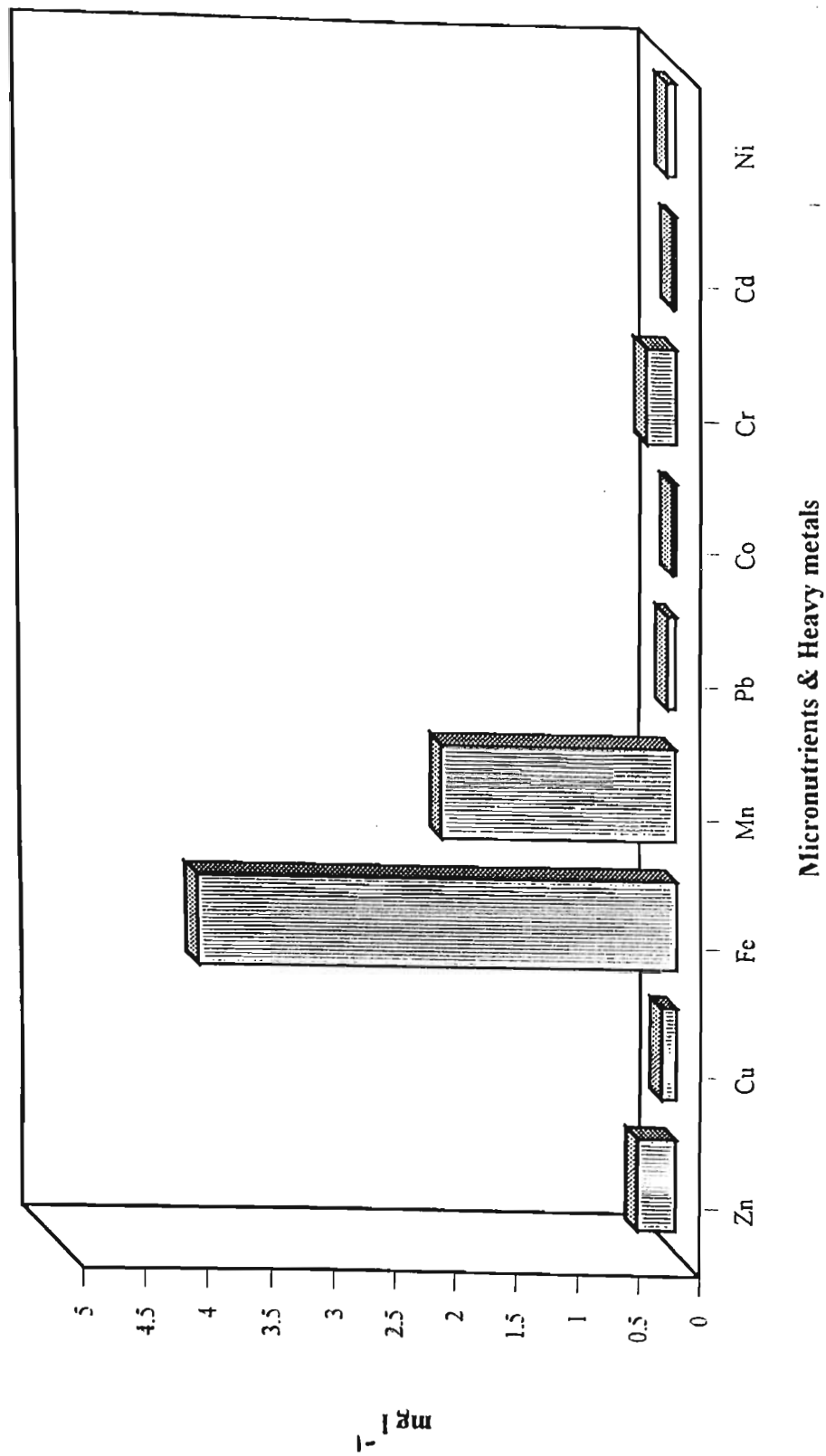
The concentration of bicarbonates of sewage water ranged from 170.8 to 305.0 mg L<sup>-1</sup> with the mean value of 215.5 mg L<sup>-1</sup>.

#### 4.1.22 Zinc (Zn)

The range of Zinc in the sewage water was 0.234 to 0.353 mg L<sup>-1</sup> with the mean value of 0.313 mg L<sup>-1</sup>.

#### 4.1.23 Copper (Cu)

The Cu content of sewage water ranged from 0.118 to 0.128 mg L<sup>-1</sup> with the mean value of 0.123 mg L<sup>-1</sup>.



**Fig. 5 : Micro nutrients and heavy metal contents of sewage water**

#### 4.1.24 Iron (Fe)

The range of Fe concentration in sewage water was 2.2 to 6.1 mg L<sup>-1</sup> with a mean value of 3.86 mg L<sup>-1</sup>.

#### 4.1.25 Manganese (Mn)

The content of Mn in sewage water ranged from 0.92 to 3.74 mg L<sup>-1</sup> with the mean value of 1.89 mg L<sup>-1</sup>.

#### 4.1.26 Lead (Pb)

The Pb content of sewage water ranged from 0.057 to 0.10 mg L<sup>-1</sup> with the mean value of 0.07 mg L<sup>-1</sup>.

#### 4.1.27 Cobalt (Co)

The Co content of sewage water ranged from 0.012 to 0.12 (mg L<sup>-1</sup>) with the mean value of 0.035 mg L<sup>-1</sup>.

#### 4.1.28 Chromium (Cr)

The Cr concentration in sewage water ranged from 0.178 to 0.408 mg L<sup>-1</sup> with the mean value of 0.243 mg L<sup>-1</sup>.

#### 4.1.29 Cadmium (Cd)

The Cd content of sewage water ranged from 0.024 to 0.032 mg L<sup>-1</sup> with the mean value of 0.027 mg L<sup>-1</sup>.

#### **4.1.30 Nickel (Ni)**

The Ni concentration of sewage water ranged from 0.032 to 0.090 mg L<sup>-1</sup> with the mean value of 0.072 mg L<sup>-1</sup>.

#### **4.1.31 Sodium Absorption Ratio (SAR)**

The SAR of sewage water ranged from 3.84 to 4.75 with a mean value of 4.17 which can be classified in to S<sub>1</sub> (Richards, 1960).

#### **4.1.32 Water class**

Depending on EC and SAR the quality of sewage water is classified under C<sub>4</sub>S<sub>1</sub> as per U.S Salinity Laboratory Classification of Soil, Irrigation water.

### **4.2 CHARACTERISTICS OF SOILS AFFECTED DUE TO SEWAGE IRRIGATION**

#### **4.2.1 Physico-chemical and chemical characteristics of surface soils of Maize Research Station, Amberpet**

##### **4.2.1.1 Particle size distribution, Textural class and colour**

The data are presented in Table 5.

#### **Sand**

The proportion of sand in the sewage irrigated surface soils ranged from 41 to 63.3 per cent with a mean value of 51.07 per cent whereas in the control it ranged from 65.4 to 75.7 with a mean value of 70.52.

**Table 5: Particle size distribution, textural class and colour of surface soils collected from Maize Research Station, Amberpet, Hyderabad**

Plot No.	Mechanical composition (%)			Textural class		Colour
	Sand	Silt	Clay			
<b>Irrigated with sewage water</b>						
S <sub>1</sub>	50.5	17	32.5	Scl	10 Y/R 5/2	Grayish brown
S <sub>2</sub>	53.6	15	31.4	Scl	10 Y/R 5/2	Grayish brown
S <sub>3</sub>	45.8	19	35.2	Scl	10 Y/R 5/1	Gray
S <sub>4</sub>	54.6	16	29.4	Scl	10 Y/R 5/1	Gray
S <sub>5</sub>	45.8	22	32.2	Scl	10 Y/R 5/1	Gray
S <sub>6</sub>	49.0	17	34.0	Sc	10 Y/R 5/2	Grayish brown
S <sub>7</sub>	51.0	14	35.0	Sc	10 Y/R 5/2	Grayish brown
S <sub>8</sub>	52.4	15	32.6	Sc	10 Y/R 5/4	Yellowish brown
S <sub>9</sub>	53.0	14	33.0	Sc	10 Y/R 5/3	Brown
S <sub>10</sub>	47.0	21	32.0	Sc	10 Y/R 5/3	Brown
S <sub>11</sub>	49.0	18	33.0	Sc	10 Y/R 5/3	Brown
S <sub>12</sub>	48.8	24	27.2	Sc	10 Y/R 5/4	Yellowish brown
S <sub>13</sub>	54.0	14	32.0	Sc	10 Y/R 5/4	Yellowish brown
S <sub>14</sub>	63.3	18	18.7	Sl	2.5 Y/R 5/8	Red
S <sub>15</sub>	56.2	20	23.8	Sl	2.5 Y/R 5/4	Reddish brown
S <sub>16</sub>	51.0	16	33.0	Scl	2.5 Y/R 4/1	dark gray
S <sub>17</sub>	51.0	15	34.0	Scl	10 Y/R 5/2	Grayish brown
S <sub>18</sub>	62.0	18	20.0	Sl	2.5 Y/R 5/8	Red
S <sub>19</sub>	61.0	16	23.0	Scl	2.5 Y/R 6/6	Light Red
S <sub>20</sub>	46.0	19	35.0	Sc	10 Y/R 4/3	Dark Brown
S <sub>21</sub>	49.8	14	36.2	Sc	10 Y/R 4/3	Dark Brown
S <sub>22</sub>	46.6	18	35.4	Sc	10 Y/R 4/2	Dark grayish brown
S <sub>23</sub>	45.0	22	33.0	Scl	10 Y/R 5/2	Grayish brown
S <sub>24</sub>	47.4	17	35.6	Sc	10 Y/R 4/1	Dark gray
S <sub>25</sub>	50.0	14	36.0	Sc	10 Y/R 5/1	Grayish brown
Range	41-63.3	14-24	18.7-36.4			
Mean	51.07	17.32	31.32			
<b>Control</b>						
C <sub>1</sub>	73.6	14	12.40	Sl	7.5 Y/R 5/2	Brown
C <sub>2</sub>	67.2	18	14.8	Sl	7.5 Y/R 5/4	Brown
C <sub>3</sub>	69.5	16	14.5	Sl	7.5 Y/R 5/6	Strong Brown
C <sub>4</sub>	70.9	17	13.1	Sl	7.5 Y/R 5/2	Brown
C <sub>5</sub>	75.7	11	13.3	Sl	7.5 Y/R 6/2	Brown
C <sub>6</sub>	71.7	12	16.3	Sl	7.5 Y/R 6/2	Pinkish gray
C <sub>7</sub>	65.4	18	16.6	Sl	7.5 Y/R 5/2	Brown
C <sub>8</sub>	69.0	14	17.0	Sl	7.5 Y/R 6/2	Pinkish gray
C <sub>9</sub>	72	16	12.0	Sl	7.5 Y/R 5/4	Brown
C <sub>10</sub>	70.2	12	11.8	Sl	7.5 Y/R 5/2	Brown
Range	65.4-75.7	11-18	11.8-17.0			
Mean	70.52	14.8	14.18			

Sc = Sandy clay      Sl = Sandy loam      Scl = Sandy clay loam

## **Silt**

The silt content of the surface soils of Maize Research Station ranged from 14 per cent to 24 per cent with a mean value of 17.32 per cent whereas in the control soils it ranged from 11.18 with a mean value of 14.8 per cent.

## **Clay**

The clay content of the surface soils of Maize Research Station ranged from 18.7 to 36.4 per cent with a mean value of 31.32 per cent whereas in the control, it ranged from 11.8 to 17.0 per cent with a mean value of 14.18 per cent.

## **Textural Class**

The Textural class of surface soils irrigated with sewage water were sandy loam to sandy clay and soils of control were sandy loam.

### **4.2.1.2 Colour of Soils**

The colour of the soils irrigated with sewage water varied from greyish brown to dark brown whereas the colour of control soils was mostly brown.

## **Physico chemical characteristics**

The data on physico-chemical characteristics of surface soils are presented in Table 6 and Illustrated in Fig. 7 and 8.



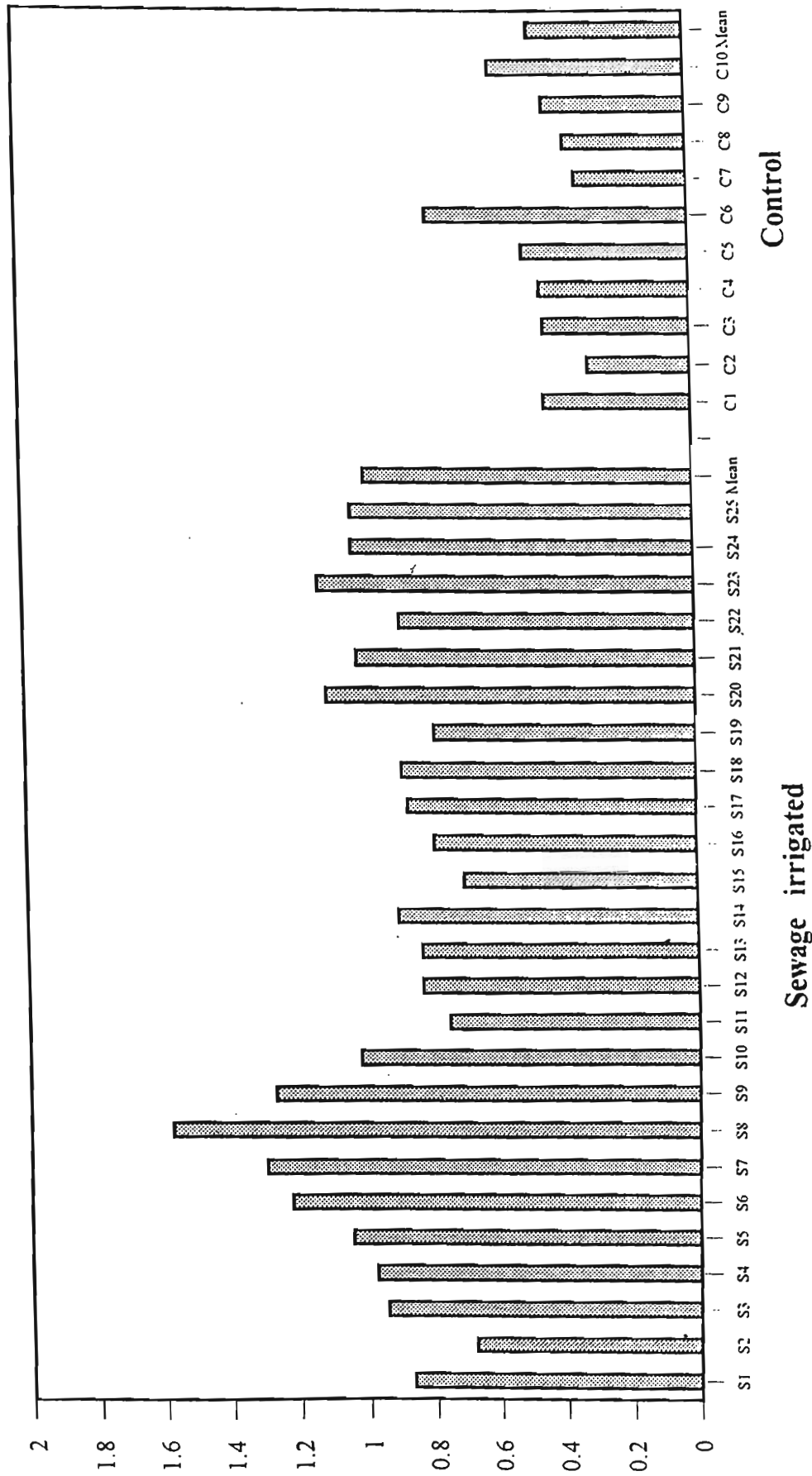


Fig. 7 : Electrical conductivity of surface soil collected from Maize Research Station  
Amberpet, Hyderabad

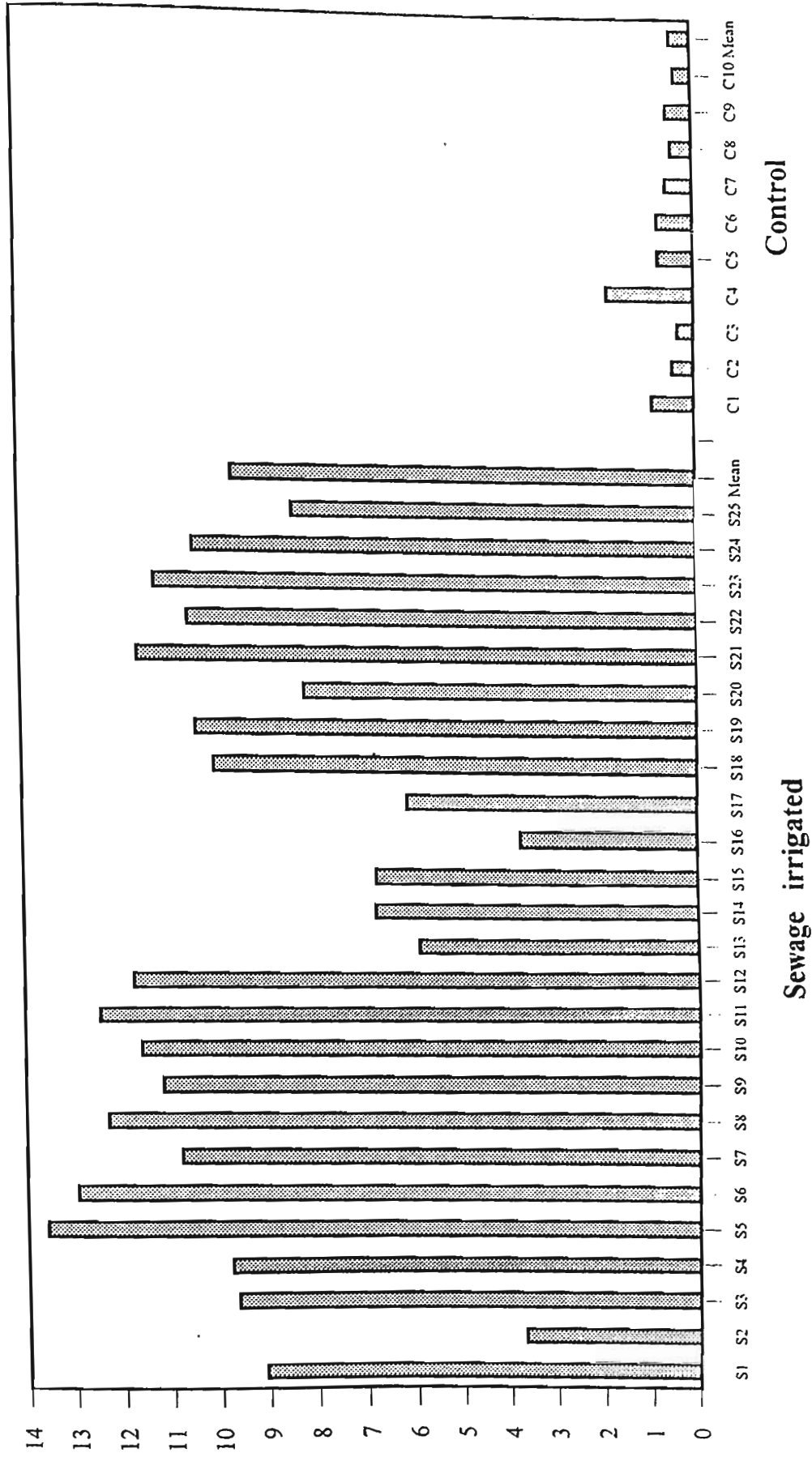


Fig. 8 : Exchangeable sodium percentage of surface soils collected from Maize Research Station  
Amberpet, Hyderabad

**Soil reaction (pH)**

The pH of the sewage irrigated surface soil samples collected from plot No. S<sub>1</sub> to S<sub>25</sub> in Maize Research Station ranged from 7.02 to 8.74 with a mean value of 8.09 while in case of control it ranged from 7.0 to 7.91 with a mean value of 7.30.

**Electrical conductivity (EC)**

The EC of the sewage irrigated surface soils of Maize Research Station ranged from 0.68 to 1.58 dS m<sup>-1</sup> with an average value of 0.99 dS m<sup>-1</sup> whereas those of control ranged from 0.31 to 0.79 with a mean value of 0.47 dS m<sup>-1</sup>.

**Cation Exchange Capacity (CEC)**

The CEC of sewage irrigated surface soil samples ranged from 17.2 to 30.4 c mol (P<sup>+</sup>) kg<sup>-1</sup> with a mean value of 26.36 c mol (P<sup>+</sup>) kg<sup>-1</sup> soil whereas those of control soil ranged from 8.7 to 14.0 with a mean value of 12.43 c mol (P<sup>+</sup>) kg<sup>-1</sup>.

**Exchangeable Sodium Percentage (ESP)**

The ESP of the sewage irrigated surface soils ranged from 3.69 to 13.57 with a mean value of 9.60 whereas that of control soil ranged from 0.33 to 0.87 with a mean value of 0.436.

### **Exchangeable Calcium and Magnesium**

Exchangeable Ca and Mg contents of sewage irrigation surface soils of Maize Research Station varied from 8.5 to 19.0; 4.0 to 9.8 c mol ( $P^-$ )  $kg^{-1}$  soil with mean values of 15.4 and 7.9 c mol ( $P^+$ )  $kg^{-1}$  soil respectively whereas the means of Ca and Mg for control soil were 7.0 and 2.22 c mol ( $P^+$ )  $kg^{-1}$  soil respectively.

### **Exchangeable Sodium and Potassium**

Exchangeable Na and K contents in surface soil samples irrigated with sewage water ranged from 1.00 to 3.72 and 0.43 to 1.07 c mol ( $P^-$ )  $kg^{-1}$  soil with mean values of 2.52 and 0.61 c mol ( $P^+$ )  $kg^{-1}$  soil respectively.

Whereas mean sodium and potassium contents of control soil were 0.078 and 0.103 c mol ( $P^+$ )  $kg^{-1}$ , respectively.

#### **4.2.1.3 Organic carbon, available nitrogen, phosphorus and potassium contents**

The data are presented in Table 7.

#### **Organic Carbon (OC)**

The organic carbon content in the surface soils irrigated with sewage water ranged from 0.754 to 1.86 per cent with a mean value of 0.97 per cent whereas the organic carbon content of control soils ranged from 0.45 to 0.61 with a mean value of 0.53 per cent.

Table 7 : Organic carbon, available nitrogen, phosphorus and potassium contents of surface soils collected from Maize Research Station, Amberpet, Hyderabad

S.No.	O.C %	N kg ha <sup>-1</sup>	P kg ha <sup>-1</sup>	K kg ha <sup>-1</sup>
<b>Sewage Irrigated</b>				
S1	1.287	216	132	753
S2	0.972	188	123	672
S3	1.860	298	105	771
S4	0.815	176	92	650
S5	1.195	267	89	998
S6	1.03	166	93	889
S7	1.110	254	92	907
S8	1.100	248	95	962
S9	0.860	230	89	826
S10	0.900	204	84	535
S11	0.980	226	110	434
S12	0.800	166	87	481
S13	0.900	188	105	517
S14	0.810	160	85	463
S15	1.090	224	95	489
S16	0.220	248	105	463
S17	0.830	169	95	617
S18	0.800	168	89	554
S19	0.740	167	88	513
S20	0.840	200	91	459
S21	0.800	163	97	463
S22	0.750	172	81	731
S23	1.000	220	89	499
S24	1.400	304	129	880
S25	1.200	241	93	717
Range	0.754- 1.86	160- 304	81- 132	431-998
Mean	0.97	211	97	638
Local	4.6	6.85	16.74	8.75
<b>Control</b>				
C1	0.53	120	25	115
C2	0.60	135	17	111
C3	0.46	106	23	112
C4	0.52	122	15	110
C5	0.54	128	17	131
C6	0.60	135	19	127
C7	0.50	103	12	122
C8	0.45	107	14	124
C9	0.52	101	28	116
C10	0.61	102	32	125
Range	0.45- 0.61	101- 135	11- 32	110- 131
Mean	0.53	116	20	120

### Available Nitrogen

The available nitrogen content in the surface soils irrigated with sewage water ranged from 160 to 304 with  $\text{kg ha}^{-1}$  mean value of 211  $\text{kg ha}^{-1}$  whereas the available nitrogen content of control soils ranged from 101 to 135  $\text{kg ha}^{-1}$  with a mean value of 116  $\text{kg ha}^{-1}$ .

### Available phosphorus

It was ranged from 81.72  $\text{kg ha}^{-1}$  to 132.5 with a mean value of 97.08  $\text{kg ha}^{-1}$ . In case of controls it ranged from 11.5 to 32.5  $\text{kg ha}^{-1}$  with a mean value of 20.19  $\text{kg ha}^{-1}$ .

The mean available phosphorus content of soils was more when irrigated with sewage water when compared to soils irrigated with normal water (control).

### Available Potassium

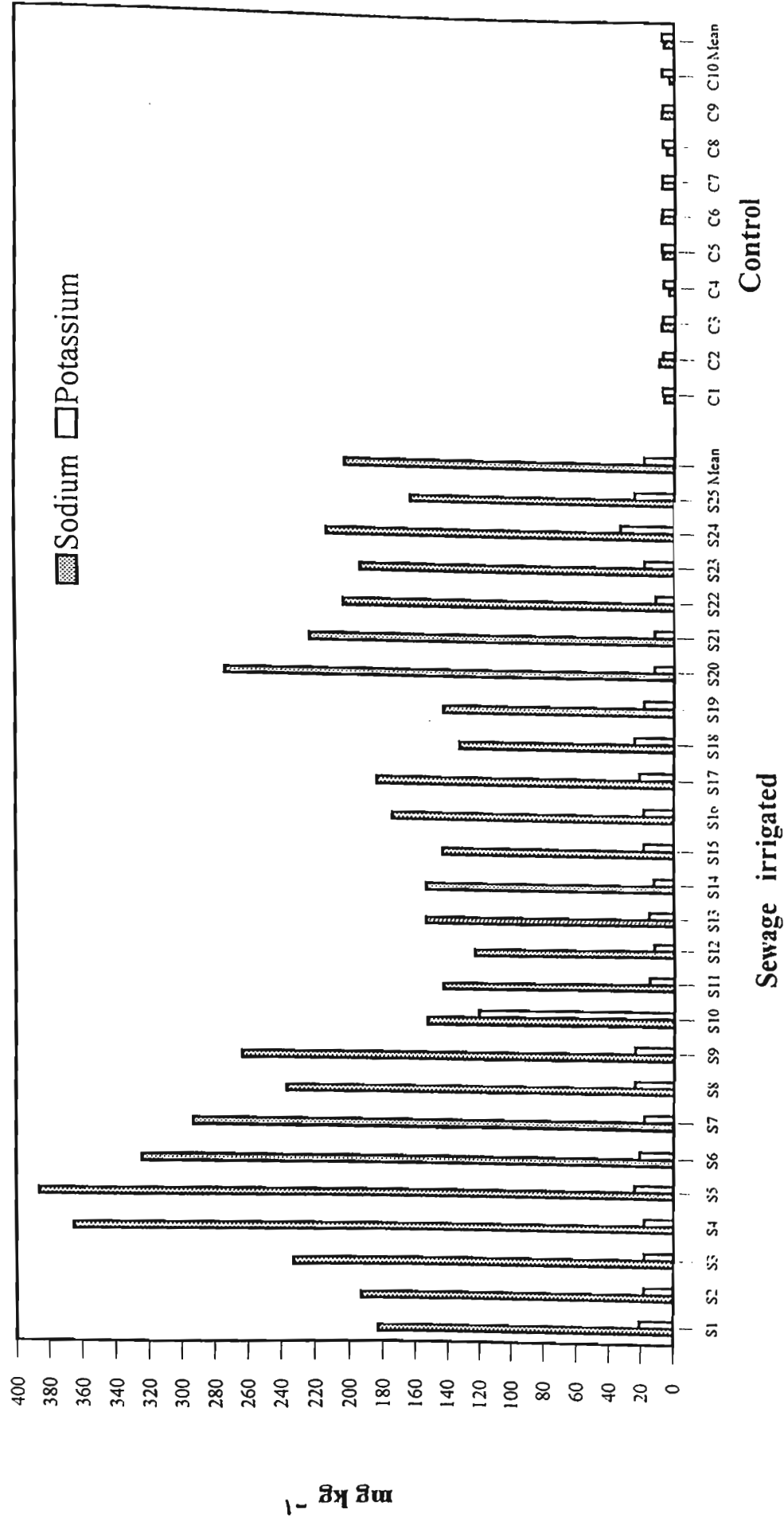
The available K ranged from 431 to 998  $\text{kg ha}^{-1}$  with a mean value of 638  $\text{kg ha}^{-1}$  whereas those of controls ranged from 110 to 134  $\text{kg ha}^{-1}$  with a mean value of 120  $\text{kg ha}^{-1}$ .

#### 4.2.1.4 Water soluble ions

The data on water soluble ions are presented in Table 8 and illustrated in Fig. 9a & 9b

Table 8: Water soluble ions in surface soils collected from Maize Research Station, Amberpet, Hyderabad

S.No	Plot No	Water soluble ion (mg kg <sup>-1</sup> )			
		Na <sup>+</sup>	K <sup>+</sup>	So <sub>4</sub> <sup>-2</sup>	Cl <sup>-</sup>
1.	S <sub>1</sub>	183	21.30	157	71.0
2.	S <sub>2</sub>	193	18.29	141	120.0
3.	S <sub>3</sub>	233	18.29	172	60.3
4.	S <sub>4</sub>	365	18.29	140	73.1
5.	S <sub>5</sub>	386	24.39	125	70.4
6.	S <sub>6</sub>	325	21.34	94	71.0
7.	S <sub>7</sub>	294	18.29	172	134
8.	S <sub>8</sub>	237	24.39	140	99
9.	S <sub>9</sub>	264	24.39	125	71.2
10.	S <sub>10</sub>	152	120.19	110	78.1
11.	S <sub>11</sub>	142	15.25	78	115.2
12.	S <sub>12</sub>	122	12.19	78	78.1
13.	S <sub>13</sub>	152	15.25	78	79.0
14.	S <sub>14</sub>	152	12.19	94	71.0
15.	S <sub>15</sub>	142	18.29	109	71.6
16.	S <sub>16</sub>	173	18.29	188	71.1
17.	S <sub>17</sub>	183	21.34	125	63.4
18.	S <sub>18</sub>	132	24.39	110	78.3
19.	S <sub>19</sub>	142	18.29	125	71.2
20.	S <sub>20</sub>	274	12.19	110	99.4
21.	S <sub>21</sub>	223	12.19	188	78.4
22.	S <sub>22</sub>	203	11.60	156	92.3
23.	S <sub>23</sub>	193	18.29	125	71.4
24.	S <sub>24</sub>	213	33.54	188	78.1
25.	S <sub>25</sub>	162	24.39	125	70.2
	Range	122-386	11.60-33.54	94-188	60.3-134.0
	Mean	202	18.7	130	85.5
CD.	8.71	6.5	11.68	10.19	
26.	C <sub>1</sub>	9.8	7.63	4.8	3.6
27.	C <sub>2</sub>	8.4	7.36	2.2	4.9
28.	C <sub>3</sub>	3.5	7.54	3.6	2.6
29.	C <sub>4</sub>	7.3	7.16	3.4	3.7
30.	C <sub>5</sub>	8.5	7.94	4.2	0.5
31.	C <sub>6</sub>	8.2	7.80	2.1	2.5
32.	C <sub>7</sub>	5.0	7.72	3.8	1.2
33.	C <sub>8</sub>	8.1	7.50	1.9	2.0
34.	C <sub>9</sub>	3.1	7.45	4.7	3.6
35.	C <sub>10</sub>	2.03	7.80	3.4	2.8
	Range	2.0-9.8	7.16-7.94	1.9-4.8	0.5-4.9
	Mean	6.3	7.59	3.4	2.7
	tcal	8.71	6.51	11.6	10.19



**Fig. 9a : Water soluble sodium and potassium of surface soils collected from Maize Research Station Amberpet, Hyderabad**

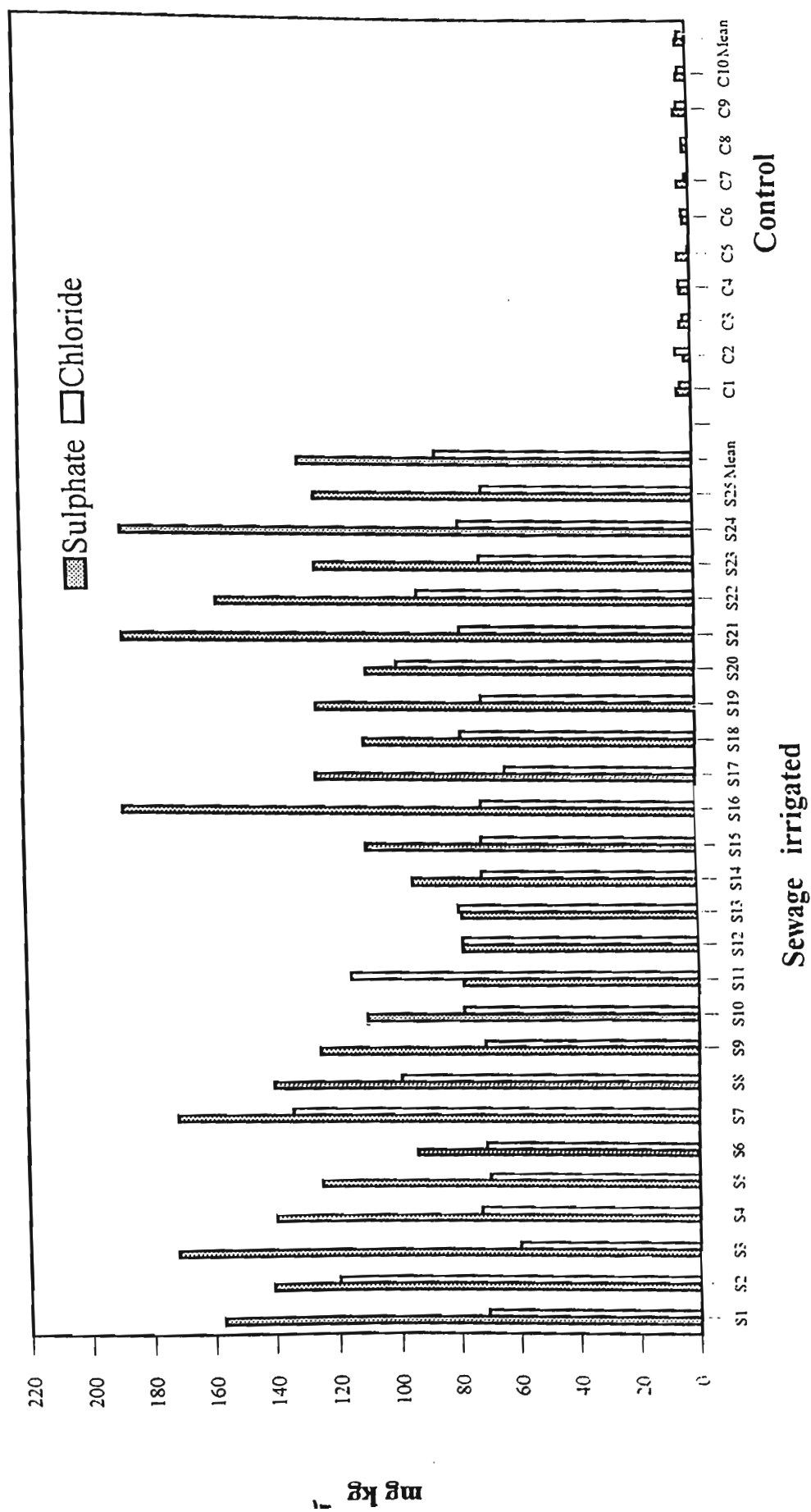


Fig. 9b : Water soluble chlorides and sulphates of surface soils collected from Maize Research Station  
Amberpet, Hyderabad

### **Water soluble sodium and potassium**

The water soluble Na and K concentrations in sewage irrigated soil samples of Maize Research Station, Amberpet ranged from 122 to 386 mg kg<sup>-1</sup> and 11.60 mg kg<sup>-1</sup> to 33.54 mg kg<sup>-1</sup> with mean values of 202 and 18.7 mg kg<sup>-1</sup>, respectively and those of control, values ranged from 2.0 to (Plot No. C<sub>10</sub>) to 9.8 (Plot No. C<sub>1</sub>) and 7.16 to 7.94 with a mean values of 6.3 and 7.59 mg kg<sup>-1</sup>, respectively.

### **Water soluble sulphates and Chlorides**

The water soluble sulphate and chloride concentrations in soil sewage irrigated soils ranged from 94 (Plot No. S<sub>14</sub>) to 188 mg kg<sup>-1</sup> and 60.3 to 134.0 mg kg<sup>-1</sup> with mean values of 130.0 and 85.5 mg kg<sup>-1</sup>, respectively and SO<sub>4</sub><sup>-2</sup> and Cl<sup>-</sup> contents of controls ranged from 1.9 to 4.8 mg kg<sup>-1</sup> and 0.5 to 4.9 mg kg<sup>-1</sup> with mean value of 3.4 and 2.7 mg kg<sup>-1</sup>, respectively.

#### **4.2.1.5 DTPA extractable micronutrients and heavy metal contents in surface soils**

The data are presented in Table 9.

### **Micronutrients**

The available Fe, Mn, Zn, Cu contents of sewage irrigated surface soils (Plot No. S<sub>1</sub> to S<sub>25</sub>) of Maize Research Station, Amberpet ranged from 14.0 to 84.6; 20.97 to 99.28; 2.66 to 20.85; 0.72 to 4.96 mg kg<sup>-1</sup> with mean values of 36.1, 53.65, 7.74 and 2.28 mg kg<sup>-1</sup> respectively. In case of control (Plot No. C<sub>1</sub> to C<sub>10</sub>) the Fe, Mn, Zn, Cu contents in soils ranged

Table 9 : DTPA extractable micronutrients and heavy metal contents  
in surface soils collected from Maize Research Station, Amberpet,  
Hyderabad

S.No.	Micronutrients (mg kg <sup>-1</sup> )				Heavy Metals (mg kg <sup>-1</sup> )				
	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	Cr
<b>Sewage Irrigated</b>									
S <sub>1</sub>	20.4	29.85	3.70	3.60	2.66	0.860	0.26	0.140	0.248
S <sub>2</sub>	23.0	63.93	5.34	1.53	3.84	0.744	0.96	0.078	0.220
S <sub>3</sub>	83.0	28.17	5.67	1.88	5.62	0.718	0.28	0.106	0.150
S <sub>4</sub>	38.0	24.65	5.86	1.11	4.28	0.544	0.25	0.076	0.270
S <sub>5</sub>	28.0	20.97	5.89	1.13	3.76	0.664	0.29	0.080	0.190
S <sub>6</sub>	25.0	37.05	7.27	3.56	6.10	0.972	0.32	0.156	0.116
S <sub>7</sub>	21.6	31.53	6.32	4.96	5.78	0.968	0.30	0.118	0.120
S <sub>8</sub>	19.9	98.13	12.96	2.98	5.62	0.956	0.20	0.176	0.110
S <sub>9</sub>	50.8	50.12	4.92	1.48	4.76	0.926	0.30	0.138	0.142
S <sub>10</sub>	20.8	30.33	5.32	3.57	5.06	0.868	0.68	0.126	0.104
S <sub>11</sub>	79.4	31.77	4.03	1.48	3.74	1.126	0.30	0.116	0.186
S <sub>12</sub>	18.0	38.25	10.04	0.72	3.36	0.844	0.26	0.126	0.118
S <sub>13</sub>	25.9	83.53	19.48	0.81	3.96	0.778	0.32	0.156	0.220
S <sub>14</sub>	82.3	25.29	3.85	1.02	2.54	0.368	0.19	0.080	0.114
S <sub>15</sub>	14.0	28.17	20.85	2.64	3.60	0.816	0.96	0.120	0.148
S <sub>16</sub>	84.6	53.85	4.59	2.40	3.50	1.534	0.48	0.098	0.144
S <sub>17</sub>	56.7	58.65	4.55	3.62	4.46	1.328	0.50	0.106	0.466
S <sub>18</sub>	24.7	30.57	7.46	1.71	4.22	0.826	0.92	0.096	0.560
S <sub>19</sub>	17.9	21.45	5.01	1.69	3.64	0.780	0.24	0.138	0.114
S <sub>20</sub>	24.5	98.73	6.28	1.01	6.88	0.864	0.28	0.102	0.112
S <sub>21</sub>	25.4	99.88	6.75	1.19	5.00	0.708	0.76	0.086	0.128
S <sub>22</sub>	14.7	91.20	6.98	1.17	4.92	0.732	0.62	0.092	0.132
S <sub>23</sub>	49.8	74.73	2.66	1.59	5.24	0.806	0.70	0.156	0.444
S <sub>24</sub>	24.6	93.45	14.67	4.61	6.32	0.736	0.32	0.128	0.204
S <sub>25</sub>	29.4	97.05	13.17	3.62	6.62	1.24	0.98	0.152	0.108
Range	14.0- 84.6	20.97- 99.88	2.66- 20.85	0.72- 4.96	2.54- 6.88	0.368- 1.534	0.19- 0.980	0.076- 0.176	0.104- 0.560
Mean	36.1	53.65	7.74	2.28	4.61	0.86	0.467	0.117	0.194
t <sub>cal</sub>	3.94	4.65	4.35	4.41	11.94	14.98	0.048	0.011	0.036
<b>Control</b>									
C <sub>1</sub>	8.13	9.00	1.30	0.62	0.080	0.051	0.045	0.016	0.050
C <sub>2</sub>	8.72	9.52	0.82	0.61	0.040	0.020	0.068	0.017	0.072
C <sub>3</sub>	5.53	9.76	0.78	0.38	0.050	0.032	0.060	0.015	0.055
C <sub>4</sub>	4.10	10.25	1.02	0.39	0.058	0.060	0.038	0.021	0.048
C <sub>5</sub>	3.85	10.82	1.20	0.37	0.084	0.056	0.035	0.016	0.042
C <sub>6</sub>	3.98	8.88	0.85	0.36	0.060	0.028	0.030	0.017	0.065
C <sub>7</sub>	9.22	11.87	0.99	0.57	0.070	0.058	0.040	0.018	0.044
C <sub>8</sub>	8.15	9.02	1.19	0.72	0.078	0.062	0.080	0.020	0.052
C <sub>9</sub>	7.96	11.80	1.23	0.69	0.080	0.025	0.065	0.020	0.044
C <sub>10</sub>	8.28	9.70	1.28	0.79	0.060	0.028	0.050	0.019	0.048
Range	3.85- 9.22	8.88- 11.87	0.78- 1.30	0.36- 0.79	0.040- 0.084	0.020- 0.062	0.030- 0.080	0.015- 0.022	0.042- 0.72
Mean	6.79	10.06	1.06	0.55	0.066	0.042	0.051	0.018	0.052

from 3.85 to 9.22; 8.88 to 11.87; 0.78 to 1.3 and 0.36 to 0.79 with mean values of 6.79, 10.06, 1.06 and 0.55 mg kg<sup>-1</sup>, respectively.

### **Heavy metals**

In case of toxic metals, the concentrations of Pb, Ni, Co, Cd, Cr in the sewage irrigated surface soils of Maize Research Station ranged from 2.54 to 6.88, 0.368 to 1.534, 0.19 to 0.98, 0.076 to 0.176 and 0.104 to 0.560 mg kg<sup>-1</sup> with mean values of 4.61, 0.86, 0.467, 0.117 and 0.194 mg kg<sup>-1</sup>, respectively. In case of controls, the concentration of Pb, Ni, Co, Cd, Cr ranged from 0.040 to 0.084, 0.020 to 0.062, 0.030 to 0.080, 0.015 to 0.022 and 0.042 to 0.72 mg kg<sup>-1</sup> with mean values of 0.066, 0.042, 0.051, 0.018 and 0.052 mg kg<sup>-1</sup>, respectively.

#### **4.2.1.6 Total micronutrients and heavy metal contents in surface soils**

The total Fe, Mn, Zn, Cu in sewage fed surface soils ranged from 1.11 to 2.98 per cent, 220 to 559, 21.35 to 96.52 and 11.6 to 22.35 mg kg<sup>-1</sup> with means of 1.89 per cent, 391, 57.57, 17.67 mg kg<sup>-1</sup> respectively while those of controls ranged from 0.77 to 1.46 per cent, 170 to 215, 11.5 to 17.1; 5.00-7.90 with means of 1.03 per cent, 191.1, 14.42 and 6.142 mg kg<sup>-1</sup> respectively (Table 10).

Table 10: Total micronutrient and heavy metal content in surface soils collected from Maize Research Station, Amberpet, Hyderabad

SP.No.	Micronutrients				Heavy Metals				
	Fe (%)	Mn	Zn	Cu	Pb	Ni	Co	Cd	Cr
	mg kg <sup>-1</sup>				mg kg <sup>-1</sup>				
<b>Sewage Irrigated</b>									
S1	2.18	388	33.75	11.46	22.0	17.75	9.25	1.12	251
S2	1.79	459	40.45	16.10	24.0	22.45	11.40	0.75	222
S3	1.84	220	46.50	11.60	32.0	17.60	6.25	0.65	181
S4	2.17	245	48.20	14.70	23.0	15.80	8.75	0.76	190
S5	2.19	334	61.05	15.10	28.0	21.96	12.85	0.80	260
S6	2.11	400	71.60	21.10	34.5	27.15	14.05	0.95	181
S7	2.15	320	79.35	22.35	32.5	24.00	11.25	1.10	183
S8	1.89	551	82.05	20.27	28.0	17.70	8.60	1.35	144
S9	2.79	357	36.85	15.96	24.5	18.35	8.90	1.20	185
S10	2.13	381	60.30	21.00	28.2	15.30	12.25	0.75	177
S11	2.91	366	33.00	20.32	24.6	24.85	8.86	0.90	266
S12	1.11	414	71.95	19.97	24.0	17.80	9.00	1.05	180
S13	1.91	521	93.75	18.88	26.5	16.55	8.50	1.11	239
S14	2.98	266	28.35	12.24	18.5	14.75	8.26	0.80	159
S15	1.57	286	21.35	16.86	22.5	16.05	19.55	1.00	200
S16	2.96	389	40.35	14.88	33.0	26.35	17.05	0.90	209
S17	1.61	307	42.00	21.80	22.5	22.45	8.85	0.95	381
S18	1.42	251	79.20	18.10	21.5	17.30	16.25	0.75	384
S19	1.22	232	40.95	17.50	23.2	16.35	8.75	0.70	220
S20	1.45	514	65.28	15.26	36.2	21.95	8.55	0.90	221
S21	1.52	553	69.75	15.00	28.0	17.20	12.24	0.62	209
S22	1.11	450	79.98	15.85	27.6	18.35	11.86	0.84	220
S23	1.58	483	23.00	16.50	30.8	19.00	12.84	1.11	357
S24	1.42	559	96.52	21.46	32.3	20.85	21.55	1.00	229
S25	1.55	514	93.76	19.60	34.5	22.35	19.82	1.05	126
Range	1.11- 2.98	220- 559	21.35- 96.52	11.60- 22.35	18.5- 36.2	14.75- 27.15	6.25- 21.55	0.62- 1.35	126- 384
Mean	1.89	339	57.57	17.67	27.29	19.6	11.82	0.924	223
Mean	0.467	5.71	5.78	11.7	13.00	14.76	4.92	0.860	10.32
<b>Control</b>									
C1	1.04	180	17.10	7.90	8.5	3.20	6.05	0.40	4.3
C2	1.46	175	11.50	6.30	4.9	2.02	6.20	0.41	6.95
C3	0.90	178	13.20	5.15	6.4	2.24	4.16	0.35	4.38
C4	0.84	182	13.90	5.05	6.7	3.70	3.60	0.32	4.25
C5	0.77	187	15.75	5.00	8.6	3.45	5.70	0.29	4.10
C6	0.79	170	11.75	5.02	6.7	2.13	3.30	0.30	5.11
C7	1.09	205	13.30	5.50	7.7	3.65	5.25	0.48	4.20
C8	1.03	211	15.25	6.90	8.0	3.80	6.35	0.50	4.45
C9	1.00	208	16.00	6.80	6.8	2.17	6.10	0.52	4.10
C10	1.06	215	16.50	7.80	5.2	2.19	5.95	0.42	4.20
Range	0.77- 1.46	170- 215	11.50- 17.10	5.00- 7.90	4.9- 8.6	2.02- 3.80	3.30- 6.35	0.29- 0.52	4.10- 6.95
Mean	1.03	191.1	14.42	6.142	6.95	2.85	5.26	0.399	4.60

The total Pb, Ni, Co, Cd, Cr concentrations in sewage fed soils of Maize Research Station, Amberpet ranged between 18.5 to 36.2; 14.75 to 27.15; 6.25 to 21.55; 0.62 to 1.35 and 126 to 384 mg kg<sup>-1</sup> with means of 27.29, 19.6, 11.82, 0.924 and 223 mg kg<sup>-1</sup> respectively while those of controls ranged from 4.9 to 8.6; 2.02 to 3.80; 3.30 to 6.35; 0.29 to 0.52 and 4.10 to 6.95 mg kg<sup>-1</sup> with means of 6.95, 2.85, 5.26, 0.399, 4.60 mg kg<sup>-1</sup> respectively (Table 10).

#### 4.2.1.7 Relative availability of micronutrients of surface soils collected from Maize Research Station, Amberpet

The data pertaining to relative availability of micronutrients of surface soils presented in Table 11.

##### Iron

The relative availability of iron in sewage irrigated surface soils ranged from 0.08 to 0.45 with a mean value of 0.19 whereas that of controls ranged from 0.05 to 0.08 with a mean of 0.067 per cent.

##### Manganese

In sewage irrigated soils, the range of relative availability of manganese is from 7.68 to 20.27 with a mean of 13.04 whereas that of control is 4.27 to 5.79 with a mean of 5.1 per cent.

##### Zinc

The relative availability of zinc in sewage irrigated soils and controls ranged from 7.96 to 20.79 with a mean of 9.87 per cent and 4.8 to 7.60 with a mean of 5.23 per cent respectively.

Table 11 : Relative availability% of micronutrients of surface soils collected from  
Maize Research Station, Amberpet 76

Plot No.	Fe	Mn	Zn	Cu
<b>Sewage Irrigated</b>				
S1	0.09	7.68	10.96	18.55
S2	0.12	13.93	13.20	9.50
S3	0.45	12.80	12.19	16.20
S4	0.17	10.06	12.15	7.55
S5	0.12	6.28	9.65	7.48
S6	0.11	9.27	10.15	16.87
S7	0.10	9.85	7.96	22.19
S8	0.1	17.82	15.79	14.70
S9	0.17	14.06	13.35	9.27
S10	0.09	7.97	8.82	17.00
S11	0.27	8.69	12.21	7.28
S12	0.16	9.25	13.95	3.60
S13	0.13	16.05	20.79	4.29
S14	0.27	9.52	13.58	8.33
S15	0.08	9.85	97.66	15.65
S16	0.28	13.84	11.37	16.12
S17	0.35	19.10	10.83	16.60
S18	0.17	12.18	9.42	9.44
S19	0.14	9.24	12.23	9.65
S20	0.17	19.21	9.62	6.61
S21	0.16	18.06	9.68	7.93
S22	0.13	20.27	8.73	7.38
S23	0.31	15.47	11.56	9.63
S24	0.17	16.73	15.20	21.48
S25	0.18	18.88	14.05	18.46
Range	0.08-0.45	7.68-20.27	7.96-20.79	3.6-22.19
Mean	0.19	13.04	9.87	12.17
<b>Control</b>				
C1	0.08	5	7.6	7.84
C2	0.06	5.26	4.8	9.68
C3	0.06	5.48	5.91	7.37
C4	0.05	5.63	7.34	7.72
C5	0.05	5.78	7.62	7.40
C6	0.05	5.22	7.23	7.17
C7	0.08	5.79	7.44	10.36
C8	0.08	4.27	7.80	10.43
C9	0.08	4.34	7.69	10.14
C10	0.08	4.51	7.76	10.12
Mean	0.067	5.1	5.23	8.82
Range	0.05-0.08	4.27-5.79	4.8-7.69	7.17-10.43

## Copper

The range of relative availability of copper in sewage irrigated surface soils varies from 3.6 to 22.19 with a mean value of 12.17 whereas in case of controls it ranged from 7.17 to 10.43 with mean of 8.82 per cent. The mean relative availabilities followed the order as  $Mn > Cu > Zn > Fe$ .

### **Relative availability of heavy metals of surface soils collected from Maize Research Station, Amberpet**

The data pertaining to relative availability of heavy metals of surface soils presented in Table 12 and Fig. 10.

## Lead

The Relative availability of Pb in surface soils irrigated with sewage water ranged from 10.6 to 20.07 with the mean value of 16.89 per cent. However in the control, it was ranged from 0.81 to 1.17 with the mean value of 0.94 per cent.

## Nickel

In sewage irrigated surface soils the relative availability of Ni ranged from 3.02 to 5.91 per cent with the mean value of 4.41 per cent and those of control ranged from 0.99 to 1.63 per cent with the mean value of 1.41 per cent.

## Cobalt

The relative availability of Co in sewage irrigated surface soils and control ranged between 1.48 and 5.66 with mean value of 3.90 and from 0.61 to 1.44 with the mean value of 0.97 per cent respectively.

Table 12 : Relative Availability of Heavy Metals of surface soils collected from  
Maize Research Station, Amberpet

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Plot No.	Pb	Ni	Co	Cd	Cr
<b>Sewage Irrigated</b>					
S <sub>1</sub>	12.09	4.84	2.81	12.5	0.09
S <sub>2</sub>	16.00	3.31	8.42	10.4	0.09
S <sub>3</sub>	17.56	4.07	4.48	16.30	0.08
S <sub>4</sub>	18.60	3.44	2.85	10.00	0.14
S <sub>5</sub>	13.42	3.02	2.25	10.00	0.07
S <sub>6</sub>	17.68	3.58	2.27	16.42	0.06
S <sub>7</sub>	17.78	4.03	2.66	10.72	0.06
S <sub>8</sub>	20.07	5.40	2.32	13.03	0.07
S <sub>9</sub>	19.42	5.04	3.37	11.5	0.07
S <sub>10</sub>	17.94	5.67	5.55	16.8	0.05
S <sub>11</sub>	15.20	4.53	3.38	12.88	0.07
S <sub>12</sub>	14.00	4.74	2.88	12.00	0.06
S <sub>13</sub>	14.94	4.70	3.76	14.05	0.09
S <sub>14</sub>	13.72	2.49	2.30	10.00	0.07
S <sub>15</sub>	16.00	5.08	4.91	12.00	0.07
S <sub>16</sub>	10.60	5.82	2.81	10.88	0.06
S <sub>17</sub>	19.82	5.91	5.64	11.15	0.12
S <sub>18</sub>	19.62	4.77	5.66	12.8	0.14
S <sub>19</sub>	15.68	4.77	2.74	19.7	0.05
S <sub>20</sub>	19.00	3.93	3.27	11.33	0.05
S <sub>21</sub>	17.85	4.11	6.20	13.8	0.06
S <sub>22</sub>	17.82	3.98	5.22	10.95	0.06
S <sub>23</sub>	17.01	4.13	5.45	14.05	0.12
S <sub>24</sub>	19.56	3.52	1.48	12.8	0.08
S <sub>25</sub>	19.18	5.54	4.94	14.47	0.08
Range	10.6-20.07	3.02-5.91	1.48-5.66	10.0-14.05	0.06-0.14
Mean	16.89	4.41	3.90	12.8	0.08
t <sub>cal</sub>	19.2	10.25	5.52	10.18	54.87
<b>Control</b>					
C <sub>1</sub>	0.94	1.59	0.74	4.00	1.16
C <sub>2</sub>	0.81	0.99	1.09	4.14	1.03
C <sub>3</sub>	0.78	1.42	1.44	4.28	1.25
C <sub>4</sub>	0.86	1.62	1.05	6.56	1.12
C <sub>5</sub>	0.97	1.62	0.61	5.51	1.03
C <sub>6</sub>	0.89	1.31	0.90	5.66	1.27
C <sub>7</sub>	0.90	1.58	0.76	3.75	1.04
C <sub>8</sub>	0.98	1.63	1.25	4.00	1.16
C <sub>9</sub>	1.17	1.15	1.06	3.84	1.07
C <sub>10</sub>	1.15	1.27	0.84	4.52	1.14
Range	0.81-1.17	0.99-1.63	0.61-1.44	3.75-6.56	1.02-1.16
Mean	0.94	1.41	0.97	4.6	1.13

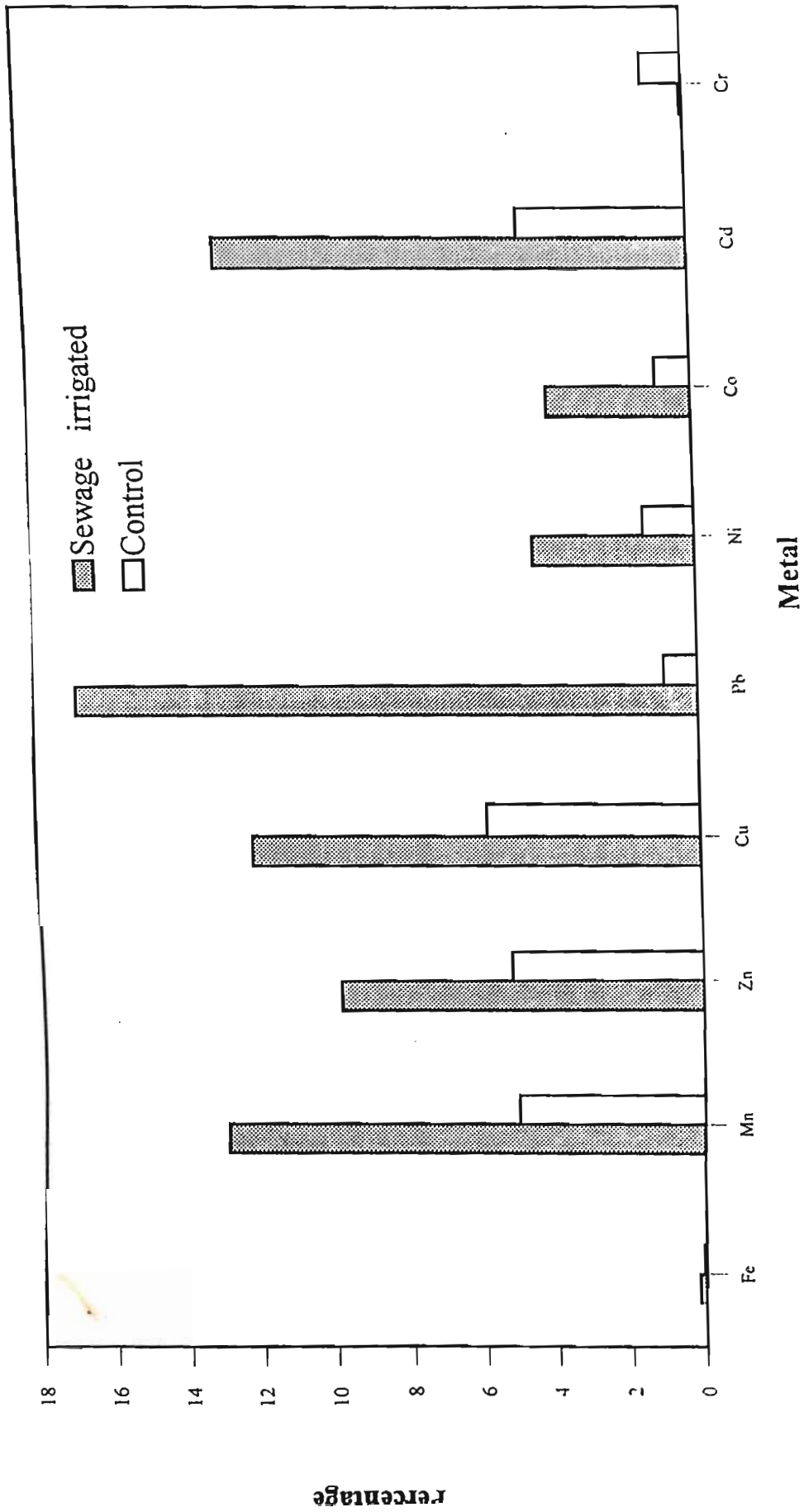


Fig. 10 : Relative availability of micronutrients and heavy metals in surface soils collected from Maize  
Research Station Amberpet, Hyderabad

## **Cadmium**

A range of 10.0 to 14.05 per cent relative availability for Cd with the mean value of 12.8 per cent was observed in surface soils irrigated with sewage whereas in control it ranged from 3.75 to 6.56 with the mean value of 4.6. Percent.

## **Chromium**

In sewage irrigated surface soils, the relative availability of Cr ranged from 0.06 to 0.14 with the mean value of 0.08 per cent and that of control ranged from 1.02 to 1.16 with the mean value of 1.13 per cent.

### **4.2.2 Physico chemical and Chemical characteristics of soil profiles of Maize Research Station, Amberpet**

#### **4.2.2.1 Particle size distribution**

The data on particle size distribution textured class and soil colour are presented in Table 13.

#### **Sand**

The sand content in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15 cm 15-30 cm and 30-45 cm ranged from 47.0 to 50.4, 40.7 to 49.3 and 36.3 to 50.9 per cent with mean values 49.06, 45.0 and 43.46 per cent respectively. Whereas the mean sand contents of control profiles C<sub>I</sub> and C<sub>II</sub> at the same depths is 73.2, 69.6 and 66.0 per cent.

**Table 13 : Particle size distribution textural classes and colour of soil profiles collected from Maize Research Station, Amberpet, Hyderabad** 83

Soil Profile No.	0-15 cm	15-30 cm	30-45 cm
<b>Sand (%)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	50.4	49.3	50.9
P <sub>2</sub>	47.0	40.7	36.3
P <sub>3</sub>	49.8	45.0	43.2
Mean	49.06	45.0	43.46
<b>Control</b>			
C <sub>1</sub>	76.8	72.2	68.8
C <sub>2</sub>	69.6	67.0	63.2
Mean	73.2	69.6	66.0
<b>Silt (%)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	18	17	15
P <sub>2</sub>	24	28	30
P <sub>3</sub>	22	25	27
Mean	21.33	23.33	24.00
<b>Control</b>			
C <sub>1</sub>	12	14	17
C <sub>2</sub>	16	17	20
Mean	14	15.5	18.5
<b>Clay (%)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	31.6	33.7	34.1
P <sub>2</sub>	29.0	31.3	33.7
P <sub>3</sub>	28.2	30.0	29.8
Mean	29.6	31.66	32.53
<b>Control</b>			
C <sub>1</sub>	11.2	13.8	14.2
C <sub>2</sub>	14.4	16.0	16.8
Mean	12.8	14.9	15.5
<b>Soil Textural Class</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	Scl	Scl	Scl
P <sub>2</sub>	Scl	Scl	cl
P <sub>3</sub>	Scl	Scl	Scl
<b>Control</b>			
C <sub>1</sub>	sl	sl	cl
C <sub>2</sub>	sl	sl	cl
<b>Soil Colour</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	10 YR 6/1 g	10 YR 6/2 lbg	10 YR 6/2 lbg
P <sub>2</sub>	10 YR 5/1 g	10 YR 5/2 gb	10 YR 4/1 dg
P <sub>3</sub>	5 YR 7/6 Ry	5 YR 7/8 Ry	5 YR 7/8 Ry
<b>Control</b>			
C <sub>1</sub>	7.5 YR 5/4 B	7.5 YR 5/2 B	7.5 YR 5/2 B
C <sub>2</sub>	7.5 YR 6/8 Ry	7.5 YR 6/6 Ry	7.5 YR 4/4 db

Scl = Sandy clay loam; cl = Clay loam; sl = Sandy loam; g = gray; lbg = light brownish gray  
 dg = dark gray; B = Brown; gb = grayish brown; Ry = Reddish yellow; db = dark brown

At 0-15 cm depth the control soils had higher sand content of 29.14 per cent over sewage irrigated soil.

At 15-30 cm depth the control soils had higher sand content of 24.6 per cent than sewage irrigated soils.

At 30-45 cm depth the control sites had sand content 22.54 per cent higher than the sewage irrigated soils.

### **Silt**

The silt content in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15 cm, 15-30 cm and 30-45 cm depth from 18 to 24, 17 to 28 and 15 to 30 per cent with mean values of 21.33, 23.33 and 24 per cent respectively whereas the mean silt percentages of control profiles C<sub>1</sub> and C<sub>2</sub> at the same depths are 14, 15.5 and 18.5 per cent respectively. At 0-15 cm depth the sewage irrigated soils had 7.33 per cent silt higher content than control.

At 30-45 cm depth the sewage irrigated soils had 5.5 per cent higher silt content than controls.

### **Clay**

The clay content of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15 cm, 15-30 cm and 30-45 cm ranged from 28.2 to 31.6, 30 to 33.7, 29.8 to 34.1 per cent respectively. With mean values of 29.6, 31.66 and 32.53 per cent whereas the mean clay percentages of control profiles C<sub>1</sub> and C<sub>2</sub> at the same depths are 12.8, 14.9 and 15.5 per cent respectively. At 0-15

cm this depth the sewage irrigated soils had 16.8 per cent higher clay content than control soils.

At 15-30 cm depth the sewage irrigated profiles had 16.76 per cent clay content than controls.

At 30-45 cm depth the sewage irrigated profiles had 16.83 per cent clay higher than control soils.

#### **a) Textural class**

The textural class of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15 and 15-30 cm depths is sandy clay loam (Scl) whereas at 30-45 cm depth the textural classes of P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> are sandy clay loam, clay loam and sandy clay loam respectively. In case of control profiles, C<sub>1</sub> and C<sub>2</sub>, the textural classes at 0-15, 15-30 and 30-45 cm depth are sandy loam, sandy loam, sandy loam and sandy loam clay loam, sandy loam respectively.

#### **b) Colour**

The colour of sewage irrigated profiles P<sub>1</sub> and P<sub>2</sub> is grey to dark grey where as that of P<sub>3</sub> is reddish yellow at all depths. In case of controls, the colour of control profile C<sub>1</sub> is brown and that of C<sub>2</sub> is light brown at all the depths.

#### **4.2.2.2 Physico-chemical characteristics**

The data are presented in tables 14, 15, 17 and 19 and illustrated in figures. 11 and 12.

Table 14 : Physico-chemical characteristics of soil profiles collected from  
Maize Research Station, Amberpet, Hyderabad

Soil Profile No.	Depth		
	0-15	15-30	30-45
<b>pH</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	7.13	7.22	7.88
P <sub>2</sub>	7.64	8.03	8.05
P <sub>3</sub>	8.20	8.24	8.32
Mean	7.65	7.83	8.08
<b>Control</b>			
C <sub>1</sub>	7.01	7.23	7.31
C <sub>2</sub>	7.21	7.54	7.97
Mean	7.11	7.39	7.64
<b>EC (dSm<sup>-1</sup>)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	0.98	0.72	0.68
P <sub>2</sub>	0.83	0.59	0.58
P <sub>3</sub>	0.40	0.33	0.35
Mean	0.74	0.55	0.53
<b>Control</b>			
C <sub>1</sub>	0.33	0.34	0.38
C <sub>2</sub>	0.31	0.33	0.39
Mean	0.32	0.335	0.385
<b>CEC (Cmol(P) Kg<sup>-1</sup> Soil<sup>-1</sup>)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	29.8	31.7	32.2
P <sub>2</sub>	27.2	29.0	30.6
P <sub>3</sub>	20.6	21.9	23.6
Mean	25.86	27.53	28.8
<b>Control</b>			
C <sub>1</sub>	9.9	10.67	10.9
C <sub>2</sub>	10.4	11.2	11.8
Mean	10.15	10.93	11.35
<b>ESP</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	12.75	12.93	13.3
P <sub>2</sub>	8.4	9.4	9.5
P <sub>3</sub>	4.2	4.0	4.3
Mean	8.45	8.7	9.03
<b>Control</b>			
C <sub>1</sub>	0.7	0.83	0.84
C <sub>2</sub>	0.38	0.55	0.72
Mean	0.54	0.69	0.78

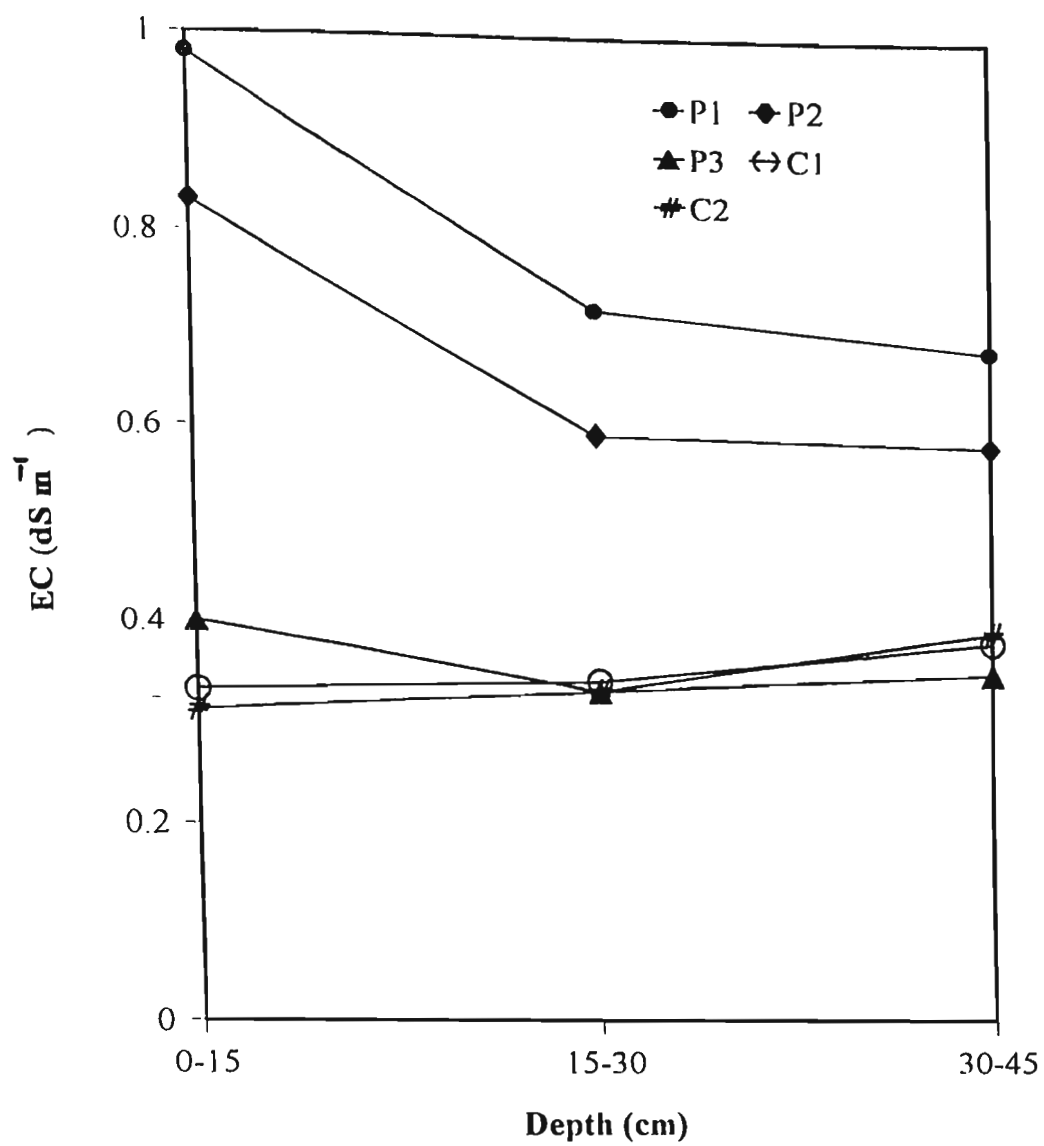


Fig. 11 : Electrical conductivity of soil profiles

## pH

The pH of the sewage irrigated profiles (P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>) at 0-15 cm depth ranged from 7.13 to 8.2 with a mean value of 7.65. At 15-30 cm depth the pH of P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> ranged from 7.22 to 8.24 with a mean value of 7.83 and at 30-45 cm the pH of P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> ranged from 7.88 to 8.32 with a mean value of 8.08. The mean pH values of control profiles C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30, 30-45 cm depths are 7.11, 7.39 and 7.64 respectively. There is significant increase in the pH at all depths.

## Electrical conductivity (EC)

The EC of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depths ranged from 0.4 to 0.98, 0.33 to 0.72 and 0.35 to 0.68 with mean values of 0.74, 0.55 and 0.53 respectively whereas the mean value EC of control profiles C<sub>1</sub> and C<sub>2</sub> at a 0-15, 15-30, 30-45 cm depths are 0.32, 0.335, 0.385 respectively. There is significant increase in EC at 0-15 cm depth in sewage irrigated profile when compared to control. At 15-30 and 30-45 cm depths the increase in EC over control is not significant.

## Cation exchange capacity (CEC)

The CEC of soils of sewage profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15, 15-30, 30-45 cm ranged from 20.6 to 29.8, 21.9 to 31.7, 23.6-35.2 with mean values of 25.86, 27.53, 28.8 respectively whereas control profiles C<sub>1</sub> and C<sub>2</sub> the CEC 0-15, 15-30 and 30-45 ranged from 9.9 to 10.4, 10.67-11.2, 10.9 to 11.8 c mol (P<sup>+</sup>) kg<sup>-1</sup> soil with mean values of 10.15, 10.13 and

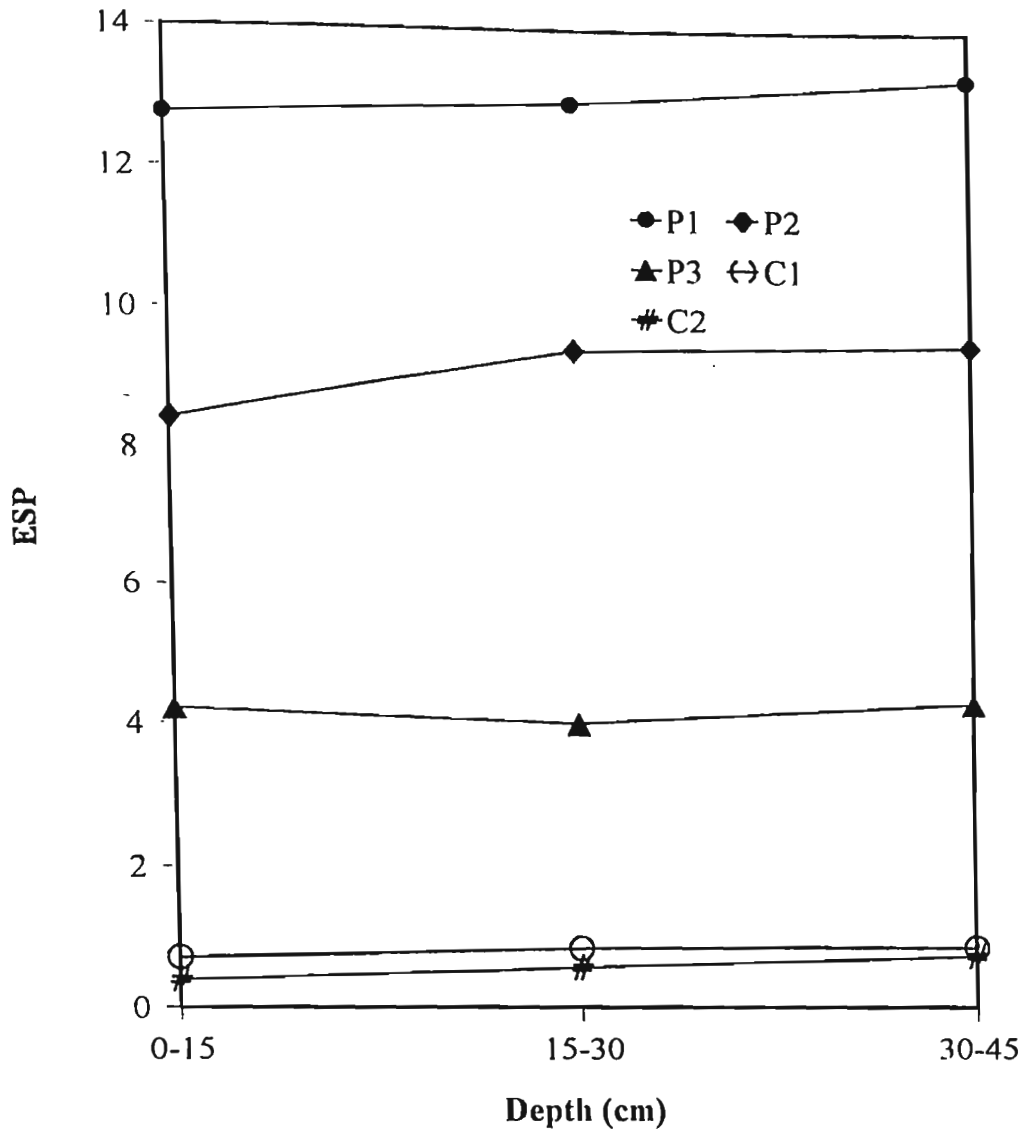


Fig. 12 : Exchangeable sodium percentage of soil profiles

11.35 c mol ( $P^+$ )  $kg^{-1}$  respectively. There is significant increase in CEC of sewage irrigated profiles when compared to control profiles at all the depths.

#### **Exchangeable sodium percentage (ESP)**

The ESP in soil samples of sewage irrigated profiles  $P_1$ ,  $P_2$ ,  $P_3$  at 0-15 cm, 15-30, 30-45 cm depths ranged from 4.2 to 12.75, 4.0 to 12.93 and 4.3 to 13.3. The ESP of control profiles  $C_1$  and  $C_2$  at 0-15, 15-30, 30-45 cm depths ranged from 0.38 to 0.7, 0.55 to 0.83, 0.72 to 0.84 with mean values of 0.54, 0.69, 0.78 respectively. There is significant increase in ESP over controls at all depths.

#### **Exchangeable calcium and magnesium**

The exchangeable calcium contents of sewage irrigated profiles  $P_1$ ,  $P_2$  and  $P_3$  at 0-15 cm, 15-30, 30-45 cm depth ranged from 11.4 to 16.2, 15.1 to 17.1, and 13.9 to 17.8 respectively with mean values of 14.3, 15.5 and 16.6 c mol ( $P^+$ )  $kg^{-1}$  soil. The exchangeable calcium contents of control profiles  $C_1$  and  $C_2$  at 0-15 cm, 15-30 and 30-45 depths ranged from 5.9 to 7.2, 6.7 to 7.8 and 6.9 to 8.3 with mean values of 6.55, 7.25 and 7.30 respectively.

The exchangeable magnesium contents of sewage irrigated profiles  $P_1$ ,  $P_2$  and  $P_3$  at 0-15, 15-30, 30-45 cm depths ranged from 4.9 to 8.1, 5.7 to 6.9, 5.9 to 7.1 c mol ( $P^+$ )  $kg^{-1}$  soil with mean values of 6.9, 6.3 and 6.36 respectively. The exchangeable magnesium contents is control profiles  $C_1$  and  $C_2$  at 0-15, 15-30 and 30-45 cm depths ranged, from 2.1 to 2.9,

**Table 15 : Exchangeable calcium, magnesium, sodium, potassium contents in soil profiles collected from Maize Research Station, Amberpet, Hyderabad**

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Soil Profile No.	Depth (cm)		
	0-15	15-30	30-45
<b>Exchangeable Calcium (c mol (P+) kg<sup>-1</sup> Soil)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	16.2	17.1	11.4
P <sub>2</sub>	15.3	16.4	13.0
P <sub>3</sub>	11.4	15.1	13.9
Mean	14.3	15.5	16.6
<b>Control</b>			
C <sub>1</sub>	5.9	6.7	6.9
C <sub>2</sub>	7.2	7.8	8.3
Mean	6.55	7.25	7.30
<b>Exchangeable Magnesium (c mol (P+) kg<sup>-1</sup> Soil)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	8.1	6.9	7.1
P <sub>2</sub>	7.7	6.4	6.1
P <sub>3</sub>	4.9	5.7	5.9
Mean	6.9	6.3	6.36
<b>Control</b>			
C <sub>1</sub>	2.9	2.8	1.6
C <sub>2</sub>	2.1	1.3	1.1
Mean	2.5	2.05	1.35
<b>Exchangeable Sodium (c mol (P+) kg<sup>-1</sup> Soil)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	3.80	4.10	4.30
P <sub>2</sub>	2.31	2.74	2.91
P <sub>3</sub>	1.13	1.21	1.28
Mean	2.41	2.68	2.83
<b>Control</b>			
C <sub>1</sub>	0.07	0.089	0.072
C <sub>2</sub>	0.040	0.062	0.085
Mean	0.055	0.0755	0.0885
<b>Exchangeable Potassium (c mol (P+) kg<sup>-1</sup> Soil)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	0.70	0.92	1.00
P <sub>2</sub>	0.41	0.53	0.61
P <sub>3</sub>	0.22	0.51	0.64
Mean	0.47	0.65	0.75
<b>Control</b>			
C <sub>1</sub>	0.07	0.09	0.120
C <sub>2</sub>	0.06	0.08	0.117
Mean	0.065	0.085	0.119

1.3 to 2.8, 1.1 to 1.6 with mean values of 2.5, 2.05 and 1.35 c mol (P<sup>+</sup>) kg<sup>-1</sup> respectively.

### **Exchangeable sodium and potassium**

The exchangeable sodium content in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depth ranged from 1.13 to 3.8, 1.21 to 4.1 and 1.28 to 4.3 with mean values of 2.41, 2.68 and 2.83 respectively. The exchangeable sodium content of control profiles C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30 and 30-45 cm depth ranged from 0.040-0.07, 0.062 to 0.089 and 0.072 to 0.085 with mean values of 0.055, 0.0755, 0.088 c mol (P<sup>+</sup>) kg<sup>-1</sup> respectively.

The exchangeable potassium content in c mol (P<sup>+</sup>) kg<sup>-1</sup> soil of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15, 15-30 and 30-45 ranged from 0.22 to 0.70, 0.51 to 0.92, 0.64 to 1.00 c mol (P<sup>+</sup>) kg<sup>-1</sup> soil respectively. The exchangeable potassium content in control profiles C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30 and 30-45 cm depth ranged from 0.06 to 0.07 and 0.08 to 0.09, 0.117-0.12 with mean values of 0.065 and 0.085, 0.1185 c mol (P<sup>+</sup>) kg<sup>-1</sup> respectively.

#### **4.2.2.3 Organic carbon, nitrogen, phosphorus and potassium**

The data is presented in Table 16 and 17.

#### **Organic carbon**

The organic carbon content in soil samples of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> ranged at 0-15, 15-30, 30-45 cm depth from 1.32-1.58, 0.51-1.09, 0.38-0.89 per cent with mean values of 1.42, 0.78, 0.58 respectively.

**Table 16 : Organic carbon, available nitrogen, phosphorus and potassium contents in soil profiles collected from Maize Research Station, Amberpet, Hyderabad**

Soil Profile No	Depth (cm)		
	0-15	15-30	30-45
<b>OC (%)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	1.58	0.75	0.48
P <sub>2</sub>	1.38	1.09	0.89
P <sub>3</sub>	1.32	0.51	0.38
Mean	1.42	0.78	0.58
<b>Control</b>			
C <sub>1</sub>	0.67	0.41	0.35
C <sub>2</sub>	0.51	0.38	0.35
Mean	0.59	0.39	0.35
<b>N (kg ha<sup>-1</sup>)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	272.13	166.20	103.48
P <sub>2</sub>	304.31	230.32	200.10
P <sub>3</sub>	282.24	112.80	84.67
Mean	286.22	169.77	129.42
<b>Control</b>			
C <sub>1</sub>	133.93	87.80	75.26
C <sub>2</sub>	109.76	81.53	78.40
Mean	121.84	84.66	76.89
<b>P (kg ha<sup>-1</sup>)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	121.52	94.61	57.72
P <sub>2</sub>	93.78	55.55	28.22
P <sub>3</sub>	89.89	49.99	29.51
Mean	101.73	66.71	38.48
<b>Control</b>			
C <sub>1</sub>	28.24	21.26	9.98
C <sub>2</sub>	17.36	9.98	6.94
Mean	22.80	15.62	8.46
<b>K(kg ha<sup>-1</sup>)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	716.68	852.76	934.41
P <sub>2</sub>	653.18	498.96	381.02
P <sub>3</sub>	580.60	480.81	217.72
Mean	438.47	610.8	728.07
<b>Control</b>			
C <sub>1</sub>	72.50	97.60	128.20
C <sub>2</sub>	118.90	85.50	60.50
Mean	66.60	91.55	123.35

Where as in control profiles C<sub>1</sub>, C<sub>2</sub> the OC content at 0-15, 15-30 and 30-45 cm depths ranged from 0.51 to 0.67, 0.38-0.41, 0.35 per cent with mean values of 0.59, 0.39, 0.35 per cent respectively.

At 0-15, 15-30 cm depths there is significant increase in organic carbon content over control where as at 30-45 cm depths the increase in organic carbon over control is not significant.

### **Available nitrogen**

The available nitrogen content in soils of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0- 15, 15-30 and 30-45 ranged from 272.13 to 282.24, 112.8 to 230.32, 84.67 to 200.00 kg ha<sup>-1</sup> with mean value of 286.22, 169.77, 124.4, kg ha<sup>-1</sup> respectively whereas in control profiles C<sub>1</sub> and C<sub>2</sub> the available nitrogen content at 0-15, 15-30 and 30-45 cm depths ranged from 109.76 to 133.93, 81.53 to 87.8 and 75.26 to 78.4 kg ha<sup>-1</sup> with mean values of 121.84, 84.66, 76.89 kg ha<sup>-1</sup> respectively.

### **Available phosphorus**

The available phosphorus content in soils of sewage irrigated profiles at 0-15, 15-30 and 30-45 cm depths ranged from 89.89 to 121.52, 49.99 to 94.61, 20.22 to 57.72 kg ha<sup>-1</sup> and the mean values are 101.73, 66.71 and 38.48 respectively whereas available P content in control profiles C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30 and 30-45 cm ranged from 17.36 to 28.24, 9.98 to 21.26, 6.94 to 9.98 kg ha<sup>-1</sup> respectively with mean values of 22.8, 15.62 and 8.46 kg ha<sup>-1</sup> respectively.

**Table 17: Mean values of some physico-chemical characteristics of soil profiles irrigated with sewage water and control**

Soil Parameter	Treatments	Depth		
		0-15 cm	15-30 cm	30-45 cm
pH	Control	7.11	7.39	7.64
	Sewage irrigated	7.65	7.83	8.08
	CD (0.05)	0.629		
EC (dS m <sup>-1</sup> )	Control	0.320	0.335	0.385
	Sewage irrigated	0.74	0.55	0.53
	CD (0.05)	0.289		
CEC (c mol kg <sup>-1</sup> )	Control	10.15	10.93	11.35
	Sewage irrigated	25.86	27.53	28.8
	CD (0.05)	5.57		
ESP (%)	Control	0.54	0.69	0.78
	Sewage irrigated	8.45	8.70	9.03
	CD (0.05)	5.57		
OC (%)	Control	0.59	0.39	0.35
	Sewage irrigated	1.42	0.78	0.58
	CD (0.05)	0.31		
Available N (kg ha <sup>-1</sup> )	Control	121.84	84.66	76.89
	Sewage irrigated	286.22	169.77	129.41
	CD (0.05)	63.84		
Available P (kg ha <sup>-1</sup> )	Control	22.80	15.60	8.46
	Sewage irrigated	101.73	66.71	38.43
	CD (0.05)	25.47		
Available K (kg ha <sup>-1</sup> )	Control	66.60	91.53	123.35
	Sewage irrigated	438.47	610.84	728.67
	CD (0.05)	275.3		

### Available potassium

The available potassium content in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15, 15-30, 30-45 cm depths ranged from 217.7 to 716.68, 480.81 to 852.76 and 580.6 to 934.4 kg ha<sup>-1</sup> with mean values of 438.47, 610.8 and 728.67 whereas in control profiles the C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30, 30-45 cm depth the available potassium contents ranged from 60.7 to 72.5, 85.5 to 99.6 and 118.3 to 128.2 with mean values of 66.6, 91.55, 123.35 kg ha<sup>-1</sup> respectively.

### Water soluble sodium and potassium

The water soluble sodium content in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15 cm, 15-30 cm and 30-45 cm depth ranged from 162.4 to 253.75, 131.95 to 152.25 and 91.35 to 314.65 ppm mg kg<sup>-1</sup> with mean values of 206.2, 142.06 and 169.16 mg kg<sup>-1</sup> ppm respectively. The water soluble sodium content of control profiles C<sub>1</sub> and C<sub>2</sub> was 6.1 to 8.2 and 4.0 to 6.1 mg kg<sup>-1</sup> ppm with the mean values of 9.0, 7.15 and 5.05 ppm respectively.

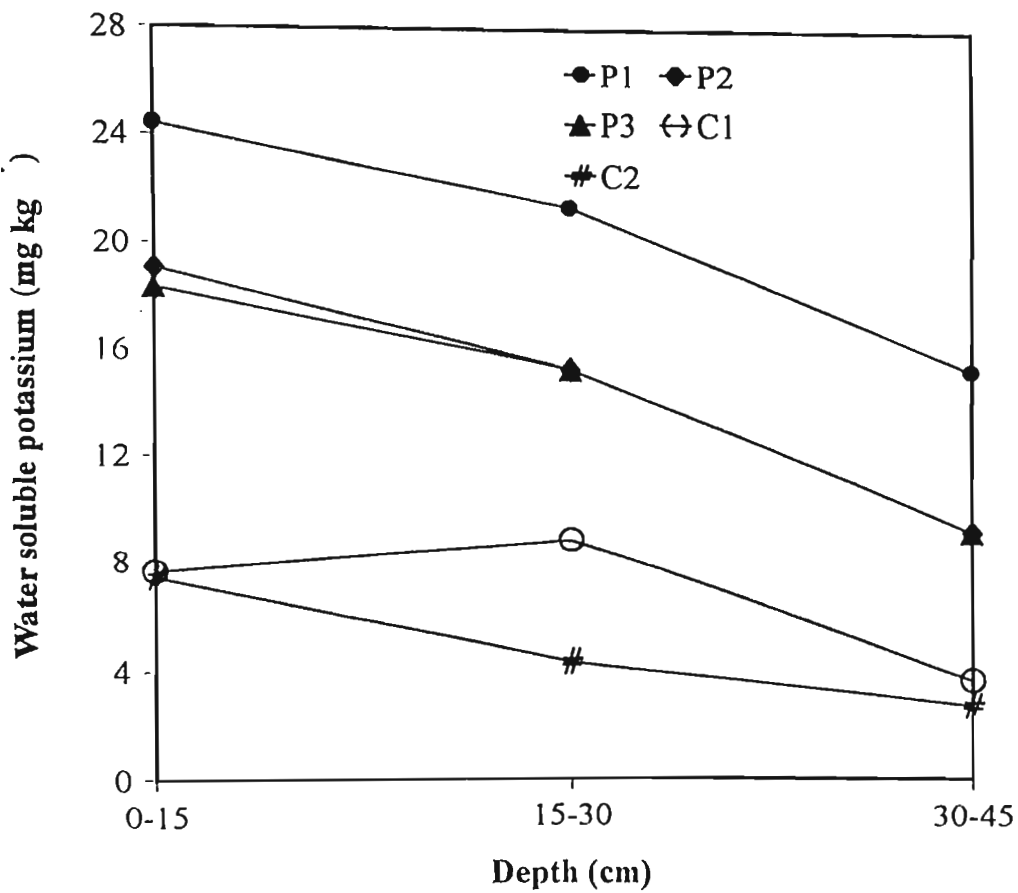
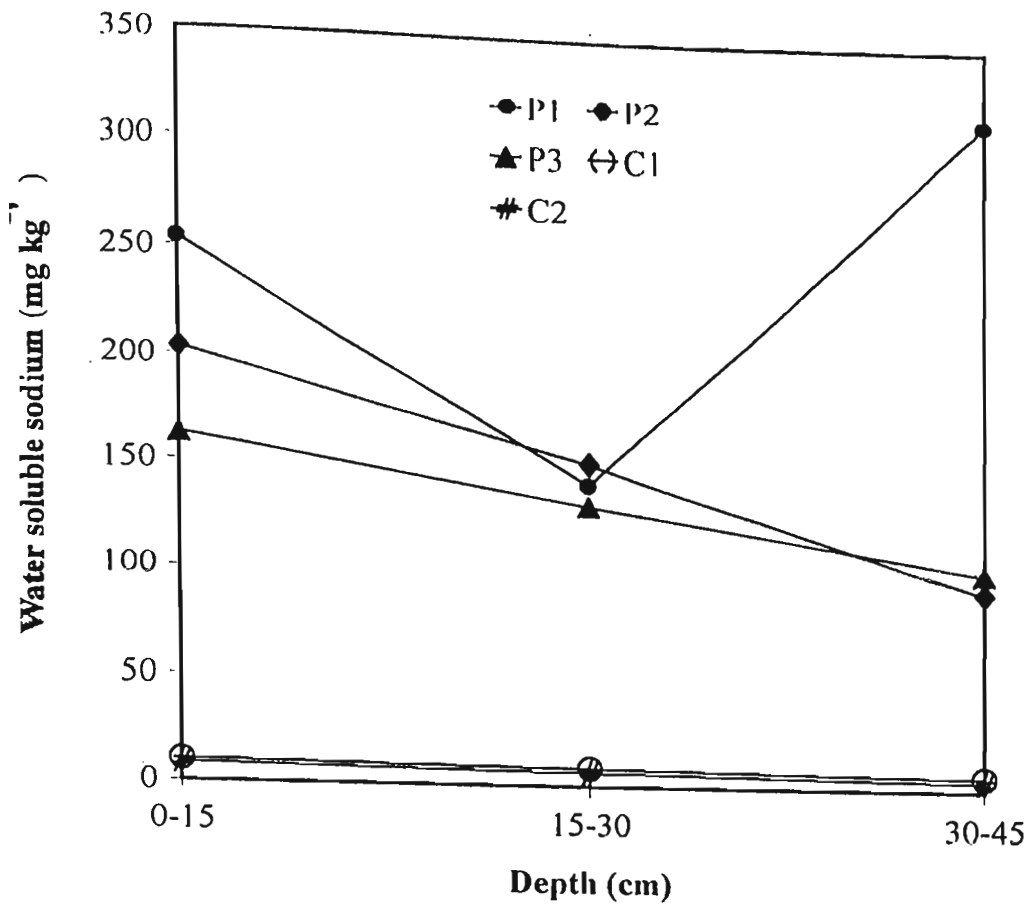
The water soluble potassium content in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15, 15-30 and 30-45 cm ranged from 18.29 to 24.39, 15.25 to 21.34 and 9.14 to 15.25 ppm with the mean values of 20.57, 17.28 and 11.77 ppm respectively. The water soluble potassium content in control profiles C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30 and 30-45 cm depth ranged from 7.36 to 7.58, 4.28 to 8.79 and 2.7 to 3.66 mg kg<sup>-1</sup> with the mean values of 7.47, 6.52 and 3.1 mg kg<sup>-1</sup>, respectively

Table 18 : Water soluble ions in soil profiles collected from Maize Research Station, Amberpet, Hyderabad

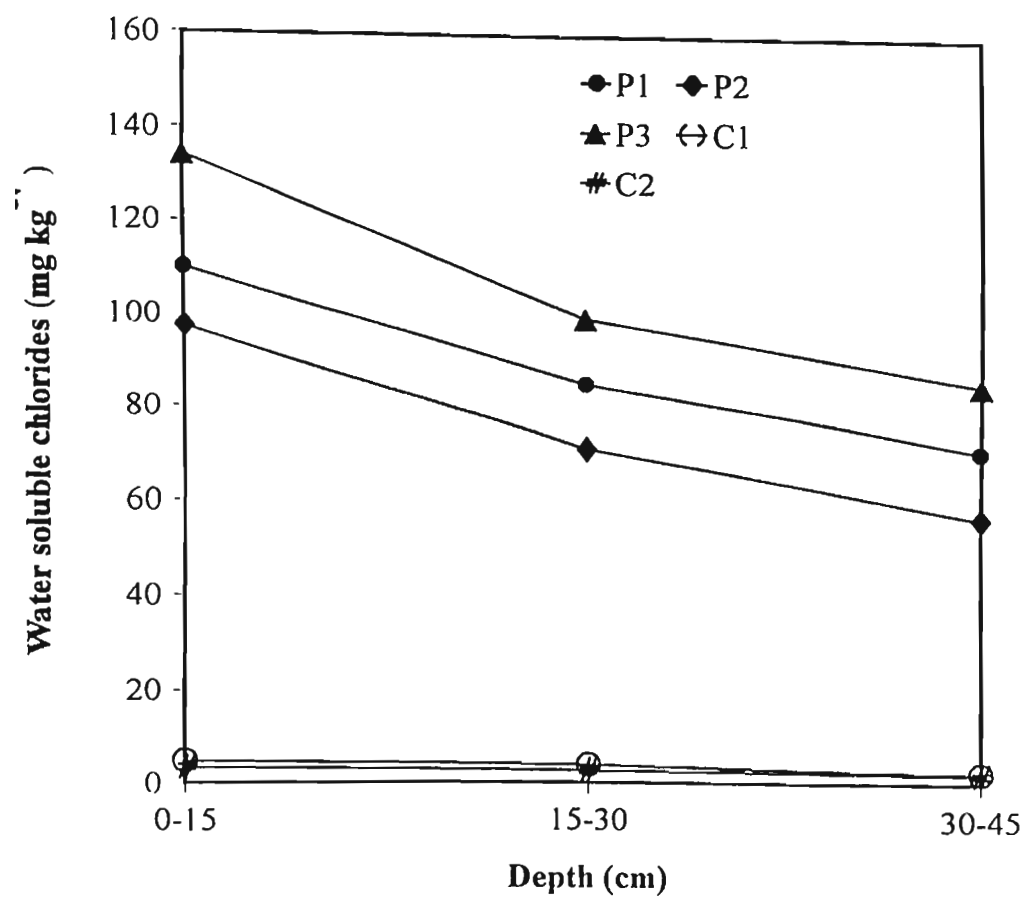
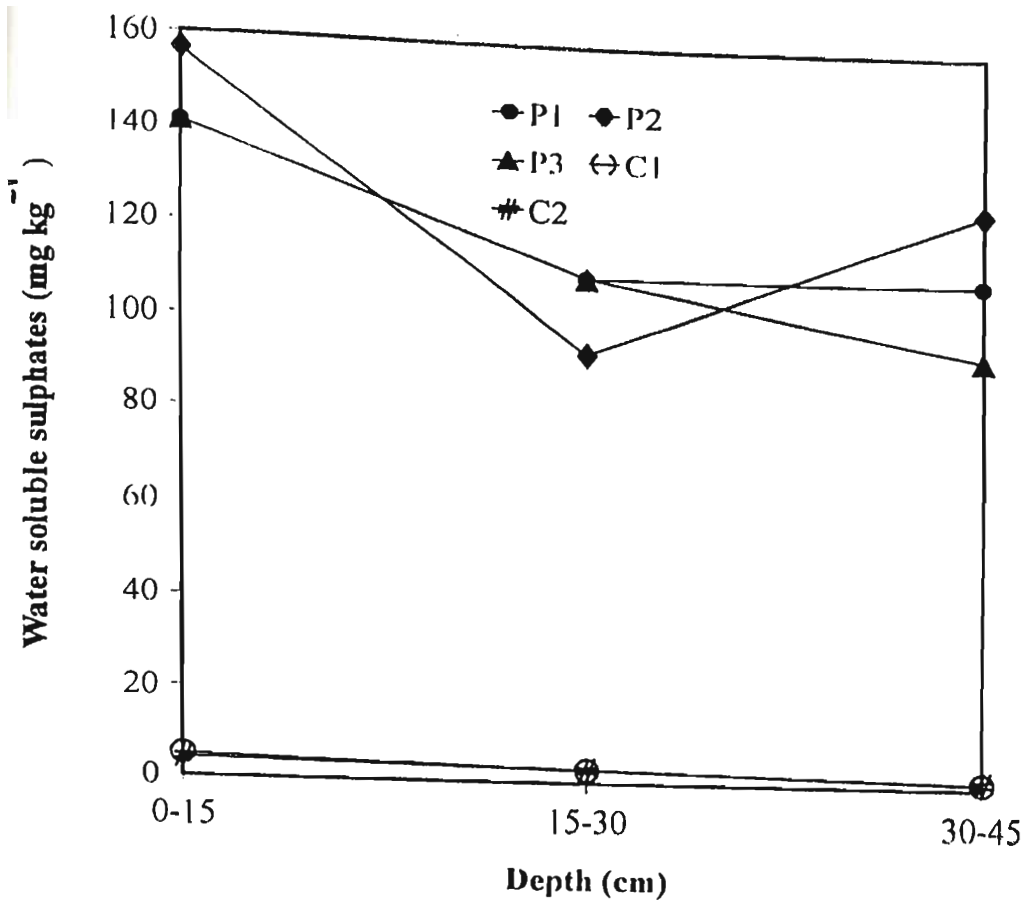
	0-15 cm	15-30 cm	30-45 cm
		<b>Na<sup>+</sup> (mg kg<sup>-1</sup>)</b>	
P <sub>1</sub>	253.75	142.10	314.65
P <sub>2</sub>	203.00	152.25	91.35
P <sub>3</sub>	162.4	131.95	101.500
Mean	206.20	142.06	169.16
C <sub>1</sub>	9.8	8.2	6.1
C <sub>2</sub>	8.2	6.1	4.0
Mean	9.0	7.15	5.05
		<b>K<sup>+</sup> (mg kg<sup>-1</sup>)</b>	
P <sub>1</sub>	24.39	21.34	15.25
P <sub>2</sub>	19.04	15.25	9.14
P <sub>3</sub>	18.29	15.25	9.14
Mean	20.57	17.28	11.17
C <sub>1</sub>	7.58	8.79	3.66
C <sub>2</sub>	7.36	4.28	2.7
Mean	7.47	6.52	3.1
		<b>SO<sub>4</sub><sup>-2</sup> (mg kg<sup>-1</sup>)</b>	
P <sub>1</sub>	140.85	109.55	109.55
P <sub>2</sub>	156.5	93.4	125.2
P <sub>3</sub>	140.85	109.55	93.9
Mean	146.06	97.5	109.5
C <sub>1</sub>	4.68	2.73	1.06
C <sub>2</sub>	3.91	2.62	1.32
Mean	4.29	2.67	1.19
		<b>Cl<sup>-</sup> (mg kg<sup>-1</sup>)</b>	
P <sub>1</sub>	110.05	85.2	70.62
P <sub>2</sub>	97.2	71.0	56.5
P <sub>3</sub>	134	99.4	85.2
Mean	113.75	85.2	70.77
C <sub>1</sub>	4.6	3.8	2.2
C <sub>2</sub>	3.2	2.6	1.9
Mean	3.9	3.2	2.05

**Table 19: Mean values of exchangeable and water soluble ions in soil profiles irrigated with sewage water and control**

Soil parameters	Treatment	Depth		
		0-15	15-30	30-45
<b>Exchangeable ions ( c mol (P<sup>+</sup>) kg<sup>-1</sup> soil)</b>				
Ca	Sewage irrigated	14.30	15.50	16.60
	Control	6.55	7.25	7.30
	CD (0.05)	2.30		
Mg	Sewage irrigated	6.90	6.30	6.36
	Control	2.50	2.05	1.35
	CD (0.05)	1.558		
Na	Sewage irrigated	2.40	2.68	2.83
	Control	0.055	0.076	0.089
	CD (0.05)	1.80		
K	Sewage irrigated	0.47	0.65	0.75
	Control	0.065	0.085	0.119
	CD (0.05)	0.330		
<b>Water soluble ion (mg kg<sup>-1</sup>)</b>				
Na <sup>+</sup>	Sewage irrigated	206.20	142.06	169.16
	Control	9.00	7.15	5.05
K <sup>+</sup>	Sewage irrigated	20.57	17.28	11.17
	Control	7.47	6.52	3.10
SO <sub>4</sub> <sup>-2</sup>	Sewage irrigated	146.06	97.50	109.50
	Control	4.29	2.67	1.19
Cl <sup>-</sup>	Sewage irrigated	113.75	85.20	70.77
	Control	3.90	3.20	2.05



**Fig. 13 : Water soluble sodium and potassium contents of soil profiles**



**Fig. 14 : Water soluble sulphate and chloride concentrations of soil profiles**

## Water soluble sulphates and chlorides

The water soluble sulphates content in sewage irrigated soil problem P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15, 15-20 and 30-45 cm depth ranged from 140.85 to 156.5, 93.4 to 109.55 and 93.9 to 125.2 mg kg<sup>-1</sup> with the mean values of 146.06, 97.5 and 109.5 ppm respectively. The water soluble sulphates content in control profiles C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30, 30-45 cm depth ranged from 3.91 to 4.68, 2.62 to 2.73 and 1.06 to 1.32 mg kg<sup>-1</sup> with mean values of 4.29, 2.67 and 1.19 mg kg<sup>-1</sup>, respectively.

The values for soluble chlorides content in sewage irrigated soil profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depth ranged from 97.2 to 134, 71 to 99.4 and 56.5 to 85.2 mg kg<sup>-1</sup> with mean values of 113.75, 85.2 and 70.77 mg kg<sup>-1</sup>, respectively. The water soluble chlorides contents in control profiles C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30 and 30-45 cm depth ranged from 3.2 to 4.6, 2.6 to 3.8 and 1.9 to 2.2 mg kg<sup>-1</sup> with mean values of 3.9, 3.2 and 2.05 mg kg<sup>-1</sup> respectively.

### 4.2.2.4 DTPA extractable micronutrients and heavy metals

The data are presented Tables 20 and 21.

#### Micronutrients

The available Fe, Mn, Zn and Cu contents in the sewage irrigated profiles, P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15 cm ranged from 33.74 to 51.29, 39.3 to 69.37, 4.89 to 11.85 and 3.74 to 4.42 mg kg<sup>-1</sup> with the mean values of 40.89, 56.39, 8.58 and 4.13 mg kg<sup>-1</sup>, respectively. In control profiles, C<sub>1</sub> and C<sub>2</sub> at the same depth they have ranged from 7.9 to 8.24, 9.21 to 11.53, 1.10

Table 20 : DTPA extractable micronutrients and heavy metal concentrations in Soil profiles of Maize Research Station, Amberpert, Hyderabad 102

Soil Profile No	0-15 cm	15-30 cm	30-45 cm
<b>MICRONUTRIENTS (mg kg<sup>-1</sup>)</b>			
<b>Fe</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	33.74	25.29	7.5
P <sub>2</sub>	51.29	35.47	22.91
P <sub>3</sub>	37.64	19.45	15.11
Mean	40.89	26.73	15.17
<b>Control</b>			
C <sub>1</sub>	8.24	7.55	7.01
C <sub>2</sub>	7.90	5.67	4.9
Mean	8.07	6.61	5.95
<b>Mn</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	69.37	56.01	22.17
P <sub>2</sub>	39.30	52.77	24.61
P <sub>3</sub>	60.52	35.90	18.33
Mean	56.39	48.22	21.70
<b>Control</b>			
C <sub>1</sub>	11.53	10.05	8.45
C <sub>2</sub>	9.21	6.25	5.61
Mean	10.37	8.15	7.03
<b>Zn</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	9.21	7.68	6.52
P <sub>2</sub>	11.65	9.82	7.63
P <sub>3</sub>	4.89	3.97	2.15
Mean	8.58	7.15	5.43
<b>Control</b>			
C <sub>1</sub>	1.59	1.44	0.55
C <sub>2</sub>	1.10	0.99	0.42
Mean	1.34	1.21	0.48
<b>Cu</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	4.42	5.48	3.10
P <sub>2</sub>	4.24	2.13	2.58
P <sub>3</sub>	3.74	2.58	2.58
Mean	4.13	3.39	2.75
<b>Control</b>			
C <sub>1</sub>	0.611	0.436	0.553
C <sub>2</sub>	0.496	0.416	0.321
Mean	0.55	0.42	0.43

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 Contd.. Table 20 : DTPA extractable micronutrients and heavy metal concentrations  
 in Soil profiles of Maize Research Station, Amberpet, Hyderabad  
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Soil Profile No	0-15 cm	15-30 cm	30-45 cm
<b>HEAVYMETALS (mg kg<sup>-1</sup>)</b>			
<b>Pb</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	7.84	7.62	6.04
P <sub>2</sub>	5.62	5.28	4.81
P <sub>3</sub>	4.12	3.62	2.92
Mean	5.86	5.50	4.25
<b>Control</b>			
C <sub>1</sub>	0.084	0.060	0.020
C <sub>2</sub>	0.060	0.040	0.020
Mean	0.072	0.05	0.02
<b>Ni</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	1.54	0.956	0.712
P <sub>2</sub>	0.852	0.496	0.434
P <sub>3</sub>	0.746	0.490	0.642
Mean	1.04	0.64	0.59
<b>Control</b>			
C <sub>1</sub>	0.060	0.033	0.023
C <sub>2</sub>	0.046	0.048	0.020
Mean	0.053	0.04	0.0215
<b>Co</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	0.96	0.68	0.22
P <sub>2</sub>	0.28	0.20	0.42
P <sub>3</sub>	1.02	0.84	0.70
Mean	1.580	0.57	0.44
<b>Control</b>			
C <sub>1</sub>	0.05	0.03	0.05
C <sub>2</sub>	0.06	0.04	0.03
Mean	0.055	0.035	0.04
<b>Cd</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	0.172	0.152	0.172
P <sub>2</sub>	0.118	0.102	0.098
P <sub>3</sub>	0.094	0.082	0.067
Mean	0.12	0.11	0.11
<b>Control</b>			
C <sub>1</sub>	0.011	0.015	0.011
C <sub>2</sub>	0.025	0.020	0.018
Mean	0.018	0.0175	0.0145
<b>Cr</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	0.248	0.116	0.110
P <sub>2</sub>	0.294	0.280	0.234
P <sub>3</sub>	0.192	0.182	0.178
Mean	0.24	0.19	0.17
<b>Control</b>			
C <sub>1</sub>	0.056	0.041	0.046
C <sub>2</sub>	0.044	0.021	0.031
Mean	0.050	0.031	0.038

**Table 21 : Mean values of DTPA extractable micronutrient and heavy metal concentrations of soils irrigated with sewage water and control**

Soil Parameter	Treatments	Depth		
		0-15 cm	15-30 cm	30-45 cm
			mg kg <sup>-1</sup>	
Fe	Control	8.07	6.61	5.95
	Sewage irrigated	40.89	26.70	15.17
	CD (0.05)	10.57		
Cu	Control	0.55	0.42	0.43
	Sewage irrigated	4.13	3.39	2.75
	CD (0.05)	1.36		
Mn	Control	10.37	8.15	7.03
	Sewage irrigated	56.39	48.22	21.70
	CD (0.05)	14.79		
Zn	Control	1.34	1.21	0.48
	Sewage irrigated	8.58	7.15	5.43
	CD (0.05)	3.91		
Pb	Control	0.07	0.05	0.02
	Sewage irrigated	5.86	5.50	4.26
	CD (0.05)	2.30		
Ni	Control	0.05	0.04	0.02
	Sewage irrigated	1.04	0.64	0.59
	CD (0.05)	0.38		
Co	Control	0.05	0.03	0.04
	Sewage irrigated	1.58	0.57	0.44
	CD (0.05)	0.42		
Cd	Control	0.018	0.017	0.015
	Sewage irrigated	0.12	0.11	0.11
	CD (0.05)	0.084		
Cr	Control	0.050	0.031	0.038
	Sewage irrigated	0.24	0.19	0.17
	CD (0.05)	0.084		

to 1.59 and 0.496 to 0.611 with the mean values of 8.07, 10.37, 1.34 and 0.55 mg kg<sup>-1</sup>, respectively.

At 15-30 cm depth the available Fe, Mn, Zn and Cu contents in the sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> ranged from 19.45 to 35.47, 35.9 to 56.01, 3.97 to 9.82 and 2.13 to 5.48 mg kg<sup>-1</sup> with the mean values of 26.73, 48.22, 7.15 and 3.39 mg kg<sup>-1</sup>, respectively. Their content in control profiles, C<sub>1</sub> and C<sub>2</sub> at same depth ranged from 5.67 to 7.55, 6.25 to 10.05, 0.99 to 1.44 and 0.416 to 0.436 mg kg<sup>-1</sup> with the mean values of 6.61, 8.15, 7.15 and 0.42 mg kg<sup>-1</sup>, respectively.

The DTPA extractable Fe, Mn, Zn and Cu contents in the sewage irrigated profiles of P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> <sup>at 30-45 cm depth</sup> ranged from 7.5 to 22.91, 18.33 to 24.61, 2.15 to 7.63 and 2.58 to 3.1 mg kg<sup>-1</sup> with the mean values of 15.17, 21.7, 5.43 and 2.75 mg kg<sup>-1</sup> respectively. In C<sub>1</sub> and C<sub>2</sub> profiles they were in the range of 4.9 to 7.01, 5.61 to 8.45, 0.42 to 0.55 and 0.321 to 0.553 mg kg<sup>-1</sup> with the mean values of 5.95, 7.03, 0.48 and 0.43 mg kg<sup>-1</sup>, respectively.

### Heavy metals

The available Pb, Ni, Co, Cd and Cr contents in the sewage irrigated profiles, P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15 cm ranged from 4.12 to 7.84, 0.746 to 1.54, 0.28 to 1.02, 0.094 to 0.172 and 0.92 to 0.294 mg kg<sup>-1</sup> with mean values of 5.86, 1.04, 1.58, 0.12 and 0.24 mg kg<sup>-1</sup>. At same depth in C<sub>1</sub> and C<sub>2</sub> profiles they ranged from 0.060 to 0.084, 0.046 to 0.060, 0.05 to

0.06, 0.011 to 0.025 and 0.044 to 0.056 mg kg<sup>-1</sup> with mean values of 0.072, 0.053, 0.055, 0.018 and 0.050 mg kg<sup>-1</sup>, respectively.

At 15-30 cm depth the available Pb, Ni, Co, Cd and Cr contents in the sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> ranged from 3.62 to 7.62, 0.490 to 0.956, 0.20 to 0.84, 0.082 to 0.152 and 0.116 to 0.280 mg kg<sup>-1</sup> with mean values of 5.5, 0.64, 0.057, 0.11 and 0.19 mg kg<sup>-1</sup>, respectively. In C<sub>1</sub> and C<sub>2</sub> profiles at same depth they ranged from 0.040 to 0.060, 0.033 to 0.048, 0.03 to 0.04, 0.015 to 0.020 and 0.021 to 0.041 mg kg<sup>-1</sup> with mean values of 0.05, 0.04, 0.035, 0.0175 and 0.031 mg kg<sup>-1</sup>, respectively.

At 30-45 cm depth, the available Pb, Ni, Co, Cd and Cr contents in three sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> ranged from 2.92 to 6.04, 0.434 to 0.712, 0.22 to 0.7, 0.067 to 0.172 and 0.110 to 0.234 mg kg<sup>-1</sup> with mean values of 4.25, 0.59, 0.44, 0.11 and 0.17 mg kg<sup>-1</sup> respectively where as in C<sub>1</sub> and C<sub>2</sub> profiles they were in the range of 0.020 to 0.020, 0.020 to 0.023, 0.03 to 0.05, 0.011 to 0.018 and 0.031 to 0.046 mg kg<sup>-1</sup>, respectively. The mean values of these elements were 0.02, 0.0215, 0.04, 0.0145 and 0.038 mg kg<sup>-1</sup>.

#### 4.2.2.5 Total micronutrients and heavy metals

The data is presented in Tables 22 and 23.

##### Total micronutrients

The total Fe, Mn, Zn and Cu contents in the sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15 cm ranged from 1.79 to 2.13 per cent, 394 to 691,

**Table 22 : Total micronutrients and heavymetal concentrations in soil profiles collected from Maize Research Station, Amberpet, Hyderabad**

Soil Profile No	Depth (cm)		
	0-15	15-30	30-45
<b>MICRO NUTRIENTS</b>			
<b>Fe (per cent)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	2.03	1.89	1.61
P <sub>2</sub>	2.13	2.02	1.11
P <sub>3</sub>	1.79	1.57	1.50
Mean	1.98	1.82	1.40
<b>Control</b>			
C <sub>1</sub>	1.49	1.09	1.03
C <sub>2</sub>	1.09	0.99	0.83
Mean	1.29	1.04	0.93
<b>Mn (mg kg<sup>-1</sup>)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	691.0	500.5	209.0
P <sub>2</sub>	394.0	328.0	220.0
P <sub>3</sub>	656.5	357.5	191.0
Mean	580.5	395.33	226.66
<b>Control</b>			
C <sub>1</sub>	215.0	192	159.83
C <sub>2</sub>	157.40	150.20	138.60
Mean	186.2	171.1	149.21
<b>Zn (mg kg<sup>-1</sup>)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	61.35	45.05	34.55
P <sub>2</sub>	86.0	69.9	48.10
P <sub>3</sub>	50.21	25.05	13.45
Mean	65.85	46.66	32.03
<b>Control</b>			
C <sub>1</sub>	16.35	8.42	4.49
C <sub>2</sub>	11.75	6.50	3.5
Mean	14.05	7.46	3.99
<b>Cu (mg kg<sup>-1</sup>)</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	15.1	8.2	2.4
P <sub>2</sub>	22.75	11.9	8.76
P <sub>3</sub>	19.6	9.5	3.8
Mean	19.5	9.86	4.98
<b>Control</b>			
C <sub>1</sub>	7.8	6.9	5.1
C <sub>2</sub>	5.9	4.7	4.0
Mean	6.85	5.8	4.55

Table 22 : Total micronutrients and heavymetal concentrations in soil profiles collected from Maize Research Station, Amberpet, Hyderabad

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Soil Profile No	Depth (cm)		
	0-15	15-30	30-45
<b>HEAVYMETALS (mg kg<sup>-1</sup>)</b>			
<b>Pb</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	34.5	32.0	28.5
P <sub>2</sub>	32.0	31.5	28.5
P <sub>3</sub>	24.5	21.5	19.2
Mean	30.33	28.33	25.40
<b>Control</b>			
C <sub>1</sub>	5.1	3.0	2.8
C <sub>2</sub>	4.55	4.2	4.15
Mean	4.82	3.6	3.47
<b>Ni</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	22.7	18.2	16.0
P <sub>2</sub>	22.0	15.8	15.2
P <sub>3</sub>	17.6	16.45	18.90
Mean	20.76	16.81	16.7
<b>Control</b>			
C <sub>1</sub>	3.65	3.10	3.01
C <sub>2</sub>	2.96	3.10	2.02
Mean	3.30	3.1	2.51
<b>Co</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	19.20	12.25	8.60
P <sub>2</sub>	9.75	7.50	6.70
P <sub>3</sub>	11.85	6.65	6.35
Mean	13.6	8.8	7.21
<b>Control</b>			
C <sub>1</sub>	7.15	5.55	3.15
C <sub>2</sub>	5.90	4.90	3.35
Mean	6.52	5.22	3.25
<b>Cd</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	0.75	0.60	0.76
P <sub>2</sub>	1.10	0.95	0.92
P <sub>3</sub>	0.8	0.85	0.75
Mean	0.88	0.8	0.81
<b>Control</b>			
C <sub>1</sub>	0.43	0.20	0.32
C <sub>2</sub>	0.50	0.32	0.28
Mean	0.68	0.26	0.3
<b>Cr</b>			
<b>Sewage Irrigated</b>			
P <sub>1</sub>	240.4	185.2	178.4
P <sub>2</sub>	229.5	190.2	160.5
P <sub>3</sub>	196.4	157.4	130.6
Mean	222.1	177.6	156.5
<b>Control</b>			
C <sub>1</sub>	4.38	4.31	4.10
C <sub>2</sub>	4.20	3.90	3.50
Mean	4.29	4.10	3.80

50.21 to 86.0 and 15.1 to 22.75 mg kg<sup>-1</sup> with the mean values of 1.98 per cent, 580.5, 65.85 and 19.5 mg kg<sup>-1</sup> and those of control profiles C<sub>1</sub>, C<sub>2</sub> at the same depth they ranged from 1.09 to 1.49 per cent, 157.4 to 215, 11.75 to 16.35 and 5.9 to 7.8 mg kg<sup>-1</sup> with the mean values of 1.29 per cent, 186.2, 14.05 and 6.85 mg kg<sup>-1</sup>, respectively.

At 15-30 cm depth the total Fe, Mn, Zn and Cu contents in the profiles irrigated with sewage water at Amberpet ranged from 1.57 to 2.02 per cent, 328 to 500.5, 25.05 to 69.9 and 8.2 to 11.9 mg kg<sup>-1</sup> with mean values of 1.82 per cent, 395.33, 46.66 and 9.86 mg kg<sup>-1</sup> respectively. In case of control profiles C<sub>1</sub> and C<sub>2</sub>, at 15-30 cm depth they were in the range of 0.99 to 1.09 per cent, 150.2 to 192, 6.5 to 8.42 and 4.7 to 6.9 mg kg<sup>-1</sup> with mean values of 1.04, 171.1, 7.46 and 5.8 mg kg<sup>-1</sup>, respectively.

In the sewage irrigated profiles, at the depth of 30-45 cm, the total Fe, Mn, Zn and Cu contents ranged from 1.11 to 1.61, 191 to 220, 13.45 to 48.1 and 2.4 to 8.76 mg kg<sup>-1</sup> with mean values of 1.4, 226.66, 32.03 and 4.98 mg kg<sup>-1</sup> and those of control profiles at the same depth they ranged from 0.83 to 1.03, 138.6 to 157.83, 3.5 to 4.49 and 4.0 to 5.1 with mean values of 0.93, 149.21, 3.99 and 4.55 mg kg<sup>-1</sup>, respectively.

#### **Total heavy metals**

The total Pb, Ni, Co, Cd and Cr contents in three sewage irrigated profiles at 0-15 cm depth ranged from 24.5 to 34.5, 17.6 to 22.7, 9.75 to 19.2, 0.8 to 1.1 and 196.4 to 240.4 with the mean values of 74.66, 20.76, 13.6, 0.88 and 221.1 mg kg<sup>-1</sup>, respectively. In control profiles they were

**Table 23 : Mean values of total micronutrients and heavy metal concentrations of soil profiles irrigated with sewage water and control**

Soil Parameter	Treatments	Depth		
		0-15 cm	15-30 cm	30-45 cm
		Per cent		
Fe	Control	1.27	1.04	0.93
	Sewage irrigated	1.98	1.82	1.40
	CD (0.05)	0.32		
		mg kg <sup>-1</sup>		
Cu	Control	6.85	5.80	4.55
	Sewage irrigated	19.5	9.86	4.98
	CD (0.05)	4.10		
Mn	Control	186.20	171.15	149.21
	Sewage irrigated	580.50	395.33	226.66
	CD (0.05)	141.27		
Zn	Control	14.05	7.46	3.99
	Sewage irrigated	65.85	46.60	32.03
	CD (0.05)	24.64		
Pb	Control	4.82	3.60	3.47
	Sewage irrigated	30.30	28.30	25.40
	CD (0.05)	6.96		
Ni	Control	3.30	3.10	2.51
	Sewage irrigated	20.76	16.81	16.70
	CD (0.05)	2.65		
Co	Control	6.52	5.22	3.25
	Sewage irrigated	13.60	8.80	7.21
	CD (0.05)	4.33		
Cd	Control	0.68	0.26	0.30
	Sewage irrigated	0.88	0.80	0.81
	CD (0.05)	0.20		
Cr	Control	4.29	4.10	3.80
	Sewage irrigated	222.10	177.60	156.50
	CD (0.05)	2.73		

4.55 to 5.1, 2.96 to 3.65, 5.9 to 7.15, 0.43 to 0.50 and 4.2 to 4.38 mg kg<sup>-1</sup> with mean values of 4.82, 3.3, 6.52, 0.68 and 4.29 mg kg<sup>-1</sup>, respectively.

At 15-30 cm depth, the total Pb, Ni, Co, Cd and Cr contents in the profiles irrigated with sewage water at Amberpet ranged from 21.5 to 32, 15.8 to 18.2, 6.65 to 12.25, 0.6 to 0.95 and 157.4 to 190.2 mg kg<sup>-1</sup> with mean values of 28.33 mg kg<sup>-1</sup>, 16.81, 8.8, 0.8 and 177.6 mg kg<sup>-1</sup> and in case of control profiles, at the same depth they ranged from 3.0 to 4.2, 3.1 to 3.1, 4.9 to 5.55, 0.2 to 0.32 and 3.9 to 4.31 mg kg<sup>-1</sup> with mean values of 3.6, 3.1, 5.22, 0.26 and 4.1 mg kg<sup>-1</sup>, respectively.

In three sewage irrigated profiles, at 30-45 cm depth, the total Pb, Ni, Co, Cd and Cr contents ranged from 19.2 to 28.5, 15.2 to 18.9, 6.35 to 8.6, 0.75 to 0.92 and 130.6 to 178.4 mg kg<sup>-1</sup> with mean values of 25.4, 16.7, 7.21, 0.81 and 156.5 mg kg<sup>-1</sup>, respectively. They were in the range of 2.8 to 4.15, 2.02 to 3.01, 3.15 to 3.35, 0.28 to 0.32 and 3.5 to 4.1 mg kg<sup>-1</sup> with the mean value of 3.47, 2.51, 3.25, 0.3 and 3.8 mg kg<sup>-1</sup>, respectively in control profiles.

#### **4.3 EFFECT OF SEWAGE WATER IRRIGATION ON MICRONUTRIENTS AND HEAVY METALS CONTENTS AND UPTAKE BY MAIZE PLANTS**

The data pertaining to the effect of sewage water irrigation on micronutrients and heavy metal concentrations in maize plant are presented in Table 25

#### 4.3.1 Micronutrient and heavy metal content

##### Iron

The Contents of iron in maize shoot ranged from 50 to 120 mg kg<sup>-1</sup>. The mean value of iron content in the entire 10 plant samples collected from sewage irrigated plots is 89.8 mg kg<sup>-1</sup>. Whereas the average content in the seed was 15 mg kg<sup>-1</sup>.

##### Manganese

The Manganese content in maize shoots ranged from 39 to 136 mg kg<sup>-1</sup>, with the mean value of 67.4 mg kg<sup>-1</sup>. The accumulation of manganese in seed was less when compared to maize shoot. The mean manganese content in the seed was 4.1 mg kg<sup>-1</sup>.

##### Zinc

The zinc contents in maize shoot ranged from 16.1 to 40.15 mg kg<sup>-1</sup> and its mean value was 23.29 mg kg<sup>-1</sup>. The mean value of zinc content in maize seed was 7 mg kg<sup>-1</sup>.

##### Cu

The contents of copper in maize shoots ranged from 2.7 to 8.2 mg kg<sup>-1</sup> whereas the mean value was 6.79 mg kg<sup>-1</sup>. The mean value of copper content in seed was 3.2 mg kg<sup>-1</sup>.

### Lead

The contents of lead in maize shoots ranged from 1.9 to 3.5 mg kg<sup>-1</sup> whereas the mean values of lead contents in 10 maize samples collected from sewage irrigated plots was 2.46 mg kg<sup>-1</sup>.

The mean values of lead content in maize seeds was 0.05 mg kg<sup>-1</sup> and was less than that in maize shoots.

### Nickel

The nickel content in maize shoots ranged from 0.45 to 0.76 mg kg<sup>-1</sup> whereas the mean value of it was 0.64 mg kg<sup>-1</sup>. The accumulation of nickel content in maize seeds was in traces.

### Cobalt

The contents of cobalt in maize shoots ranged from 0.005 to 0.092 mg kg<sup>-1</sup> with a mean value of 0.026 mg kg<sup>-1</sup>.

### Cadmium

The contents of cadmium in maize shoots ranged from traces to 0.195 mg kg<sup>-1</sup>. The mean value of cadmium content was 0.106 mg kg<sup>-1</sup>.

The average value of cadmium content of maize seeds was 0.06 mg kg<sup>-1</sup>.

Table 24 : Effect of sewage water irrigation on micronutrients and heavy metal concentrations in maize plants

S.No	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	Cr
	mg kg <sup>-1</sup>								
1.	95	131	16.1	7.1	2.4	0.45	0.013	0.1	ND
2.	100	136	18.3	7.4	2.1	0.65	0.052	0.1	0.090
3.	120	39	19.2	8.0	2.0	0.50	0.041	0.125	0.12
4.	70	58	26.75	7.6	2.15	0.70	0.016	0.195	0.39
5.	50	46	40.15	6.2	1.9	0.65	0.092	0.140	0.22
6.	75	43	21.75	5.5	2.6	0.75	0.008	0.120	0.20
7.	82	48	25.6	7.3	2.8	0.69	0.005	ND	ND
8.	100	62	21.2	7.9	3.5	0.70	0.006	0.15	0.28
9.	96	52	27.2	2.7	3.0	0.76	0.007	ND	0.15
10.	110	59	16.55	8.2	2.24	0.60	0.050	0.133	0.19
Range	50-120	39-136	16.1-40.15	2.7-8.2	1.9-3.5	0.45-0.76	0.005-0.092	0-0.195	0-0.39
Mean	89.8	67.4	25.09	6.79	2.46	0.64	0.026	0.106	0.152

### Maize Grain

Plot No.	mg kg <sup>-1</sup>								
	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	Cr
1.	17	4.3	8.0	3.0	0.06	ND	ND	0.07	0.09
2.	13	3.9	6.0	4.4	0.04	ND	ND	0.05	0.07
3.	14	4.1	9.0	3.0	0.07	ND	ND	0.09	0.06
4.	11	5.2	8.0	3.4	0.05	ND	ND	0.09	0.07
5.	20	3.0	4.0	2.2	0.03	ND	ND	0.05	0.11
Mean	15	4.1	7	3.2	0.05	ND	ND	0.06	0.08
Range	11-20	3-5.2	4-9	2.2-4.4	0.03-0.07	-	-	0.04-0.09	0.06-1.1

## **Chromium**

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The chromium content in maize shoots ranged from traces to 0.39 mg kg<sup>-1</sup> and the mean value was 0.152 mg kg<sup>-1</sup>.

The mean value of chromium content in maize seeds was 0.08 mg kg<sup>-1</sup>.

### **4.3.2 Micronutrients and heavy metal uptake**

The data pertaining to effect of sewage water irrigation on uptake of micronutrients and heavy metals by Maize Plants are presented in Table 2.5

## **Iron**

The uptake of iron in maize plants irrigated by sewage water ranged from 329 to 7360 mg plant<sup>-1</sup> with the mean values of 5614 mg plant<sup>-1</sup>.

## **Manganese**

In sewage irrigated soil the uptake of Mn by maize plant ranged from 2369 to 7682 mg plant<sup>-1</sup> with the mean value of 4135 mg plant<sup>-1</sup>.

## **Zinc**

In maize plants, irrigated by sewage water, the Zn uptake ranged from 929 to 2643 mg plant<sup>-1</sup> with the mean value of 1464 mg plant<sup>-1</sup>.

Table 25 : Uptake of micronutrients and heavy metals by maize plants irrigated with sewage water

S.No	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	Cr
1	5484.35	7562.63	929.45	409.88	138.55	25.97	0.750	5.773	ND
2	5649	7682.64	1033.76	418.02	118.62	36.712	2.93	5.65	5.08
3	7291	2369	1166	486	121.5	30.5	2.49	7.59	7.29
4	4208	3486	1608	457	129	42.08	0.961	11.72	23.44
5	3292	3028	2643	408	125	42.79	6.05	9.21	14.48
6	4245	2434	1231	311	147	42.45	0.45	6.70	11.32
7	5114	2993	1596	455	174	43.03	0.312	ND	ND
8	6883	4267	1459	543	240	48.18	0.412	10.32	19.27
9	6616	3583	1874	186	206	52.37	0.482	ND	10.38
10	7360	3947	1107	548	149	40.14	3.345	8.899	12.71
Range	3292-7360	2369-7682	929-2643	186-548	118-240	25.9-52.3	0.31-3.34	Traces-11.72	Traces-19.27
Mean	5614	4135	1464	422	154.7	40.42	1.82	6.58	10.39

## Copper

The Cu uptake by maize plant irrigated with sewage water ranged from 166 to 548 mg plant<sup>-1</sup> with the mean value of 422 mg plant<sup>-1</sup>.

## Lead

The uptake of heavy metal Pb ranged between 118 to 240 mg plant<sup>-1</sup> with mean value of 154.7 mg plant<sup>-1</sup> in sewage irrigated maize plant.

## Nickel

In the maize plant irrigated by sewage water the uptake of Ni ranged between 25.9 to 52.3 mg plant<sup>-1</sup> with mean value of 40.42 mg plant<sup>-1</sup>.

## Cobalt

In the sewage irrigated maize plant, the uptake of Co ranged from 0.31 to 3.34 mg plant<sup>-1</sup> with mean value of 1.82 mg plant<sup>-1</sup>.

## Cadmium

The uptake of Cd in maize plant that is irrigated by sewage water ranged from traces to 11.72 mg plant<sup>-1</sup> with the mean value of 6.58 mg plant<sup>-1</sup>.

## Chromium

In maize plant that is irrigated with sewage water the uptake of Cr ranged from traces to 19.27 mg plant<sup>-1</sup> with the mean value of 10.39 mg plant<sup>-1</sup>.

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## *DISCUSSION*

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## DISCUSSION

The results of the research work carried out on impact of sewage irrigation on soil chemical properties, described in preceding chapter are discussed in the following paragraphs.

### 5.1 CHARACTERISTICS OF SEWAGE WATER

The sewage water entering into Maize Research Station, Amberpet, Hyderabad comprised mainly of domestic wastes generated from Hyderabad city. However, the characterisation of sewage water carried at Amberpet Research Station revealed that a large number of heavy metals are also being carried out in this water. This may be probably due to contamination of industrial effluents into this domestic sewage canal.

The data on the physical and chemical characteristics of sewage water used for irrigation are presented in Table 4 and figures 2 to 6.

The mean pH of the sewage water sample used for irrigation ranged from 7.1 to 8.5 depending upon the time of sampling with the mean value of 7.73. These sewage water samples were slightly alkaline in reaction. The pH values of these sewage water used for crop irrigation at Maize Research Station, Amberpet are within the permissible range for irrigation use. The tolerance limits of pH for irrigation vary between 6-9 (Desai *et al.*, 1990). Kale *et al.* (1992) also reported that the pH values of the sewage water used for crop irrigation at Amberpet, were between 6.9 -7.5 and were within permissible range. The high content of bicarbonates (170.8 to 305 mg L<sup>-1</sup>)

coupled with sodium (198.6 to 264.6 mg L<sup>-1</sup>) must have contributed for alkalinity of sewage water.

The soluble salt content of sewage water used for crop irrigation ranged from 2.58 to 4.07 with the mean value of 3.31 and can be attributed to high contents of sulphates and chlorides (Table 4). The soluble salt content was low during winter period and subsequently raised during summer as temperature increased.

The mean COD values of sewage water samples collected at different periods ranged from 192 to 864 mg L<sup>-1</sup> with a mean of 545.33 mg L<sup>-1</sup>. Lakshminenon and Bhattacharya (1988) reported COD values of 247.5 to 305 mg L<sup>-1</sup> in sewage water at Delhi after treatment. Varma *et al.* (1977) and Behera *et al.* (1990) reported higher COD values in sewage water contaminated with effluents of industries. The higher COD values in the present is a cause for concern and as discussed elsewhere the sewage water must have been contaminated with industrial effluents.

The mean BOD value of sewage water used for irrigation was 213.8 mg L<sup>-1</sup> indicating low organic matter in the sewage water. NEERI (1985) reported that sewage BOD varies within the range of 200-500 mg L<sup>-1</sup> and can be used for irrigation purposes. Therefore present BOD values of the sewage water at Amberpet falls within this safer limit. Shrabanisom *et al.* (1994) and Hosetti *et al.* (1994) reported the BOD values of raw sewage effluents as 105.5 and 308 mg L<sup>-1</sup> respectively at different places.

The dissolved oxygen content of sewage water ranged from 3.72 to 4.68 with a mean value of 4.16 mg L<sup>-1</sup>. Similar results were reported by Manohar and Subramanyam (1992) and Hosetti *et al.* (1994) and were of opinion that certain dissolved oxygen values have to be maintained for the growth of aquatic life and for purification of stream.

The hazards generally encountered with waste waters are due to high content of total salts. Excess total salts may affect the germination and growth of plants when these waters are used for irrigation. Total solids in the raw sewage water used for crop irrigation of Maize Research Station, Amberpet varied from 1844 to 2650 mg L<sup>-1</sup> with a mean of 2223.3 mg L<sup>-1</sup>. The mean total dissolved salts and mean total suspended solids of sewage water were 1806.3 and 417 mg L<sup>-1</sup> respectively. Mean total dissolved solids of sewage water used for irrigation at Maize Research Station, Amberpet was below the critical level given by Tandon (1995). The total solids are also within the tolerance limits for irrigation.

The essential major nutrient contents such as nitrogen, phosphorus and potassium are in the range of 31.2 to 45.3, 4.5 to 10.43 and 24.4 to 31.28 mg L<sup>-1</sup> with mean values of 37.8, 6.84 and 24.5 mg L<sup>-1</sup>, respectively. Hence this sewage water used for irrigation was rich in nutrients. These nutrients will be well utilised by the plants when these sewage waters are used for irrigation. This is one of the aspects for which concentration is being made to use sewage water for crop production. Similar results of high amount of these nutrients in sewage water were reported by Shrabami Som *et al.* (1994) and Mitra and Gupta (1997) at Calcutta. The mean nitrate

nitrogen in raw sewage water used for irrigation was  $0.55 \text{ mg L}^{-1}$  which was within the range of limit prescribed for irrigation purpose by WHO (1984). Manoharan and Subramanyam (1992) reported that the domestic sewage water contained  $0.3 \text{ mg L}^{-1}$  nitrates at Tirucharapalli.

Chloride content of sewage water ranged from 823 to  $1463 \text{ mg L}^{-1}$  depending upon the time of sampling with mean value of  $1011 \text{ mg L}^{-1}$ . This value was above the desirable limit ( $250 \text{ mg L}^{-1}$ ) prescribed by Indian Standards (1982) and Bureau of Indian Standards (1991). Mitra and Gupta (1997) reported that the mean concentration of chlorides to the extent of  $422.7 \text{ mg L}^{-1}$  in raw sewage water in Calcutta city and was above the desirable limit ( $250 \text{ mg L}^{-1}$ ).

The mean sulphate content of sewage water was  $475.5 \text{ mg L}^{-1}$  which was much more above the tolerable limit of  $10\text{-}14 \text{ mg L}^{-1}$  for irrigation purposes suggested by Desai *et al.* (1990). This value is also above the desirable limit as suggested by Indian Standards (1992).

Calcium and Magnesium contents of sewage water used for crop irrigation varied from 124 to  $160 \text{ mg L}^{-1}$  and  $43.73$  to  $65.66 \text{ mg L}^{-1}$ , respectively with mean values of  $136.66$  and  $52.68 \text{ mg L}^{-1}$ , respectively. These mean values are above the undesirable limits of 75 and  $30 \text{ mg L}^{-1}$ , respectively for calcium and magnesium as per the specifications of Bureau of Indian Standards (1991)

The sodium absorption ratio of sewage water ranged of from 3.84 to 4.75 with a mean value of 4.17 which is higher than the critical level 3.0 for irrigation purpose as suggested by Indian Standards (1982).

The range of zinc in sewage water was 0.234 to 0.353 mg L<sup>-1</sup> with a mean value of 0.313 mg L<sup>-1</sup> which is far below the safe limit (15 mg L<sup>-1</sup>) for land application (IS, 1982).

In case of copper and iron, their mean contents in sewage water were 0.123 and 3.86 mg L<sup>-1</sup> respectively and are well with in recommended maximum permissible concentrations of these elements (FAO, 1973; FAO, 1985). However the mean manganese content was 1.89 mg L<sup>-1</sup> and was beyond the maximum permissible limit of 0.2 mg L<sup>-1</sup> as prescribed by Pratt (1972). The manganese content of sewage waters at Sheeladhar Institute experimental farm also varied from 10.6 to 306 mg L<sup>-1</sup> (Misra *et al.* 1992).

Among the heavy metal ions in the sewage water used for irrigation, two categories can be made. Those heavy metals which are in small quantities and are below the critical limits. Lead, Cobalt and Nickel contents in sewage water were 0.07, 0.036 and 0.072 mg L<sup>-1</sup> respectively and were below the safe levels of 5.0, 0.05 and 0.2 mg L<sup>-1</sup> respectively (FAO, 1985 and Tandon (1995).

On the otherhand, the mean contents of chromium and cadmium in sewage water were 0.243 and 0.027 mg L<sup>-1</sup> respectively. These levels are beyond the tolerable limits as prescribed by FAO (1985), for irrigation purpose. Misra *et al.* (1992) and Shrabanisom *et al.* (1994) also reported

that the cadmium and chromium concentrations in sewage water of their study were beyond the maximum permissible limits. The content of lead, in the sewage water of the previous study was within the tolerable limits.

It is evident from preceding discussion that the sewage water entering into Maize Research Station, Amberpet has distinct characteristics of its own. Various parameters studied indicated that this water contains many elements and has characters within the tolerable limits for irrigation purpose. However characteristics like Cd content, Cr content, soluble salt content and COD were beyond the permissible limits. Thus, in order to avoid the loading of heavy metal concentrations on surface soils and to have better purification of the sewage stream, these waters may be treated before letting it into Amberpet farm to avoid longterm undesirable effects.

## **5.2 EFFECT OF SEWAGE IRRIGATION ON SOIL PROPERTIES**

Soil samples (surface and profile) were analysed for different properties and results presented in previous pages (49 to 116) are discussed in the following paragraphs.

### **5.2.1 Effect on surface soil properties**

The sand per cent of the surface soils irrigated with sewage water ranged from 41 to 63.3 with a mean of 51.07 whereas that of control soil ranged from 65.4 to 75.7 with a mean of 70.52 (Table 5). The sand content of surface soils irrigated with sewage water was less than that of control, and this was due to relatively higher content of clay resulting from sedimentation of sewage water. The silt per cent of the surface soils irrigated

with sewage water in Maize Research Station, Amberpet ranged from 14 to 24 per cent with a mean value of 17.32 whereas that of control soil ranged from 11 to 18 with a mean of 14.8 (Table 5). The soils irrigated with sewage water had higher silt per cent than control. This is due to the fact that irrigation with sewage water does carry fine silt particles with it (Table 5). The clay per cent of sewage irrigated surface soils ranged from 18.7 to 36.4 per cent with a mean of 31.32 per cent. On the otherhand clay content of control soils ranged from 11.8 to 17.0 per cent with a mean of 14.18 per cent. All the sewage irrigated soils had higher clay content than control. The increase in clay content in sewage fed soils is due to sedimentation of fine particles present in the sewage water (Table 5).

In general, in the soils irrigated with sewage water, the sand content was significantly lower than the control soils where as the silt and clay contents were significantly higher than the control. Similar observations were reported by Azad *et al.* (1987).

The pH of the surface soils which were irrigated with sewage water ranged from 7.02 to 8.74 with a mean value of 8.09 whereas the pH of control ranged from 7.0-7.91 with a mean of 7.3 (Table 6). Out of 25 sewage irrigated samples collected 21 soils (84 %) had the pH values more than the control and are slightly alkaline. The variation in pH values were due to the contamination by sewage water generated by the surroundings of Hyderabad city. Similar results were reported by Azad *et al.* (1987), Maiti *et al.* (1992), Tiwari *et al.* (1996) and Bhupal Raj *et al.* (1997).

The EC (1:2) of the sewage irrigated surface soils ranged from 0.68 to 1.58  $\text{dSm}^{-1}$  with a mean value of 0.99  $\text{dSm}^{-1}$ . The EC of surface soils of control ranged from 0.31 to 0.79  $\text{dSm}^{-1}$  with a mean value of 0.47  $\text{dSm}^{-1}$  (Table 6). The increase in total soluble salt contents in sewage fed soils compared to control soil is due to high contents of soluble salts (3.31  $\text{dSm}^{-1}$ ) in sewage water used for irrigation (Table 4). The high EC in sewage irrigated soils is due to high amounts of soluble salts such as chlorides, sulphates and bicarbonates due to contamination. Similar findings were reported by Sharma *et al.* 1994 and Tiwari *et al.* (1996).

The CEC of the sewage irrigated surface samples ranged from 17.2 to 30.4  $\text{cmol (P}^+) \text{ kg}^{-1}$  with a mean value of 26.36  $\text{cmol (P}^+) \text{ kg}^{-1}$  whereas the CEC of control soils ranged from 8.7-14.0  $\text{cmol (P}^+) \text{ kg}^{-1}$  with a mean value of 12.43  $\text{cmol (P}^+) \text{ kg}^{-1}$ . The CEC of all sewage irrigated soil samples (Table 6) is significantly higher than controls. This is due to higher clay content (Table 5), organic carbon (Table 7) in soils irrigated with sewage water.

The exchangeable sodium percentage of sewage irrigated surface soils ranged from 3.69 to 13.59 with a mean of 9.60 whereas that of control ranged from 0.33 to 0.87 with mean value of 0.436. The mean ESP of all surface soils samples irrigated with sewage water is higher than that of control samples (Irrigated with normal water). This may be due to higher concentration of sodium in sewage water.

Exchangeable Ca and Mg contents of sewage irrigated surface soil samples ranged from 8.5 to 19.0  $\text{cmol (P}^+) \text{ kg}^{-1}$  soil and 4.9 to 9.8  $\text{cmol (P}^+) \text{ kg}^{-1}$  soil.

mol (P<sup>+</sup>) kg<sup>-1</sup> soil with mean value of 15.4 and 7.9 € mol (P<sup>+</sup>) kg<sup>-1</sup> respectively. Whereas the mean values of control soil for calcium and magnisium was 7.0 and 2.22 € mol (P<sup>+</sup>) kg<sup>-1</sup>. All the soil samples irrigated with sewage water had higher exchangeable Ca and Mg than control soils. This may be due to higher calcium and magnesium contents of sewage water as reflected in data presented in Table 4. Similar results were reported by Maiti *et al.* (1992). The high conent of calcium in sewage irrigated soils may be due to binding of calcium with fulvic acid which is important constituent of sewage (Lakshminenon and Bhattacharya, 1988).

Exchangeable Na and K of the surface soils ranged from 1.00 to 3.72 and 0.43 to 1.07 with mean value of 2.52 and 0.61 € mol (P<sup>+</sup>) kg<sup>-1</sup> whereas those of controls ranged from 0.032 to 0.195 and 0.10 to 0.124 € mol (P<sup>+</sup>) kg<sup>-1</sup>. With mean values of 0.078 and 0.103 € mol (P<sup>+</sup>) kg<sup>-1</sup>. All the sewage treated soils had higher Exchangeable Na and K contents than control which was due to addition of Na and K through the sewage water (Table 6).

The organic carbon content in the surface soils irrigated with sewage water ranged from 0.754 to 1.86 per cent with a mean value of 0.97 per cent. In case of controls the organic carbon content varied from 0.45 to 0.61 per cent with a mean of 0.53 per cent (Table 7). The organic carbon of all the sewage irrigated soils was higher when compared to controls. Higher amount of organic matter in sewage water fed soils appears to be a consequence of the higher content of organic matter in the sewage

water. Similar findings were reported by Azad *et al.* (1987), Tiwari *et al.* (1996) and Bhupal Raj *et al.* (1997).

The available nitrogen content in surface soils irrigated with sewage water at Maize Research Station, Amberpet ranged from 160 to 304 kg ha<sup>-1</sup> with a mean of 211 kg ha<sup>-1</sup> (Table 7). The soils are medium in available nitrogen. The available nitrogen content in control soils ranged between 101 to 135 kg ha<sup>-1</sup> with a mean of 116 kg ha<sup>-1</sup> and these soils are low in available nitrogen. However there is a significant increase in available nitrogen in all the soils irrigated with sewage water when compared to control which is apparently associated with build up of organic matter due to continuous addition of sewage water. This observation is in corroboration to the findings of Azad *et al.* (1987) and Maiti *et al.* (1992). Higher organic carbon content contributed for higher available nitrogen in sewage treated plots.

In sewage fed soils of Maize Research Station, Amberpet the available phosphorus content ranged from 81-132 kg ha<sup>-1</sup> with a mean of 97 kg ha<sup>-1</sup> (Table 7), whereas the available phosphorus content of controls ranged from 11 to 32 kg ha<sup>-1</sup> with a mean of 20 kg ha<sup>-1</sup>. There is a significant increase in available phosphorus content in sewage fed soils when compared to control which can be attributed to the fact that considerable amount of phosphorus present in the sewage water which was due to the use of detergents for washing Waldeigh (1967). Azad *et al.* (1987) reported that on an average the amount of P delivered in metropolitan sewage effluent amounted to 2 pounds per person per year, and that sewage wastes from a city of one million people would contain one thousand pounds of P per year.

The available potassium content of soils irrigated with sewage water ranged from 431 to 998 kg ha<sup>-1</sup> with a mean value of 638 kg ha<sup>-1</sup>. These soils are very high in available potassium. In case of control soils the available potassium ranged from 110 to 131 kg ha<sup>-1</sup> with a mean of 120 kg ha<sup>-1</sup>. The control soils are low to medium in available potassium content (Table 7). The significant higher amount of available potassium content in soils irrigated with sewage water when compared to control might be due to continuous irrigation with sewage water rich in potassium. Maiti *et al.* (1992) also reported moderate to high levels of available K in sewage fed soils in Culcatta city.

The water soluble Na and K concentrations in surface soils irrigated with sewage water ranged from 122 to 386 mg kg<sup>-1</sup> and 11.60 to 33.54 with means of 202 mg kg<sup>-1</sup> and 18.7 mg kg<sup>-1</sup> and those of control ranged from 2.0 - 9.8 mg kg<sup>-1</sup> and 7.16 - 7.94 mg kg<sup>-1</sup> with means of 6.3 mg kg<sup>-1</sup> and 7.59 mg kg<sup>-1</sup> respectively (Table 8). The water soluble Na and K concentrations were more in all the soils irrigated with sewage water, than in control which may be due to higher content of those elements in the sewage water.

The water soluble sulphate and chloride concentrations in soils irrigated with sewage water ranged from 94 to 188 and 60.3 to 134.0 mg kg<sup>-1</sup> with means of 130 and 85.5 mg kg<sup>-1</sup> respectively whereas those of controls ranged from 1.9 to 4.8 and 0.5 to 4.9 mg kg<sup>-1</sup> with means of 3.4 and 2.7 mg kg<sup>-1</sup> respectively (Table 8). There is significant increase in water soluble sulphate and chloride content in sewage irrigated soils when compared

to control. This may be due to contamination of soils with chlorides and sulphates rich sewage water. Similar trend was observed by Lalkansal *et al.* (1993) in soils irrigated with water of Hakimwala drain at Amritsar.

The available Fe, Mn, Zn, Cu in surface soils ranged from 14.0 to 84.6; 20.97 to 99.88; 2.66 to 20.85 and 0.72 to 4.96 mg kg<sup>-1</sup> with means of 36.1, 53.65, 7.74 and 2.28 mg kg<sup>-1</sup> respectively while those of controls ranged from 3.85 to 9.22, 8.88 to 11.87; 0.78 to 1.30 and 0.36 to 0.79 mg kg<sup>-1</sup> with means of 6.79, 10.06, 1.06, 0.55 mg kg<sup>-1</sup> respectively (Table 9).

The available Fe content in all the sewage irrigated surface soils was significantly higher than the control (Table 9). This was due to irrigation with sewage water containing high amount of iron 3.86 mg l<sup>-1</sup> (Table 4). The high amount of available iron in sewage irrigated soils is also attributed to high amounts organic carbon, clay and silt content in these soils. These observations are in association with findings of Azad (1994).

The DTPA extractable manganese, zinc and copper are significantly higher in surface soils irrigated with sewage water when compared to in control soils (Table 9). The higher amount of DTPA extractable micronutrients was due to continuous irrigation with sewage water containing higher amount of micronutrients (Table 4). These results are in conformity with the findings of Khuhad *et al.* (1989) and Jayabhaskaran and Sreeramulu (1996).

**High organic carbon** and high clay content of Amberpet soils, restricts the downward mobility of metals. These observations are in

corroboration with findings of Kuhad *et al.* (1989), Jayabhaskaran and Sreeramulu (1996).

The DTPA extractable Pb, Ni, Co, Cd and Cr contents of surface soils irrigated with sewage water ranged from 2.54 to 6.88; 0.368 to 1.534; 0.19 to 0.980; 0.076 to 0.176 and 0.104 to 0.560 mg kg<sup>-1</sup> with means of 4.61, 0.86, 0.467, 0.117, 0.194 mg kg<sup>-1</sup> respectively, while those of controls ranged from 0.040 to 0.084, 0.020 to 0.062; 0.030 to 0.080; 0.015 to 0.022 and 0.042 to 0.720 mg kg<sup>-1</sup>, with means of 0.066, 0.042, 0.051, 0.018, 0.052 mg kg<sup>-1</sup> respectively (Table 9). All the DTPA extractable heavy metal contents are significantly higher in sewage irrigated soils when compared to controls, this might be due to reduced mobility of these metals into lower horizons which resulted in accumulation in surface layer. Bhpal Raj *et al.* (1997) also reported similar results with regard to heavy metals in sewage water used for irrigation along the Musi River in Hyderabad. DTPA extractable metal contents observed in sewage irrigated soils were several times higher than the contents in normal soil as shown Pb 69.8; Ni 20.5; Cr 16.2; Co 9.1; Zn 7.3; Cd 6.5; Mn 5.33; Fe 5.32; and Cu 4.1. The order of contamination in soil with sewage irrigation was Pb > Ni > Cr > Co > Zn > Cd > Mn > Fe > Cu. Continuous usage of raw sewage with aerial contamination from automobile exhausts and presence of metals (Cd, Pb and Cr) as an impurity in fertilizers have probably contributed to high accumulation of these metals in surface soils.

The total Fe, Mn, Zn and Cu in sewage fed surface soils ranged from 1.11 to 2.98 per cent, 220 to 559, 21.35 to 96.52 and 11.6 to

22.35 mg kg<sup>-1</sup> with means of 1.89 per cent, 391, 57.57, 17.67 mg kg<sup>-1</sup> respectively while those of controls ranged from 0.77 to 1.46 per cent, 170 to 215, 11.5 to 17.1; 5.00-7.90 with means of 1.03 per cent, 191.1, 14.42 and 6.142 mg kg<sup>-1</sup> respectively (Table 10). There is significant increase in total Fe, Mn, Zn contents in soils irrigated with sewage water over the controls. However in case of copper, eventhough there is an increase in its content over control, the increase is not significant.

Sewage water irrigation for the past 45 years might have resulted in the accumulation of these metals in soils. These observations are in corroboration with findings of Jayabhaskaran and Sreeramulu (1986) and Bhupal Raj (1997).

The total heavy metal contents Pb, Ni, Co, Cd and Cr in sewage fed soils of Maize Research Station, Amberpet ranged between 18.5 to 36.2; 14.75 to 27.15; 6.25 to 21.55; 0.62 to 1.35 and 126 to 384 mg kg<sup>-1</sup> with means of 27.29, 19.6, 11.82, 0.924, 223 mg kg<sup>-1</sup> respectively while those of controls ranged from 4.9 to 8.6; 2.02 to 3.80; 3.30 to 6.35; 0.29 to 0.52 and 4.10 to 6.95 mg kg<sup>-1</sup> with means of 6.95, 2.85, 5.26, 0.399, 4.60 mg kg<sup>-1</sup> respectively (Table 10).

The total heavy metal contents in sewage fed soils were high several times higher than in normal soil as shown Zn 3.99; Cu 2.88; Fe 1.83; Mn 2.04; Pb 3.93; Cd 2.33, Ni 6.88; Co 2.24 and Cr 48.5. The order of contamination was in order of Fe > Cr > Ni > Zn > Pb > Cu > Cd > Co > Mn. Continuous use of sewage water for irrigation over the years might have contributed to higher amounts of these metals in the soils. These

results are in conformity with the findings of Azad (1986), Kushad *et al.* (1989), Misra and Dinesh Mani (1993) and Bhupal Raj *et al.* (1997).

#### **Relative availability of micronutrients and heavy metals**

The mean relative availability of iron, manganese, zinc and copper in sewage irrigated surface soils of Maize Research Station, Amberpet are 0.19, 13.04, 9.87 and 12.17 per cent respectively (Table 11), whereas the mean relative availability of the respective elements in control soils are 0.067, 5.1, 5.23 and 8.82 per cent respectively. The relative availability of all the micronutrients is higher in sewage irrigated soils when compared to controls. The relative availability of micronutrients followed the order as  $Mn > Cu > Zn > Fe$ .

The mean relative availability of lead, nickel, cobalt, cadmium, chromium in sewage irrigated surface soils are 16.89, 4.41, 3.9, 12.8, 0.08 per cent respectively and the mean relative availability of same elements in control are 0.94, 1.41, 0.97, 4.6 and 1.13 per cent respectively. The mean relative availability of lead, nickel, cobalt and chromium are higher in sewage irrigated soils than the control whereas in case of chromium mean relative availability is less in sewage irrigated soils than control. The relative availability of heavy metals followed the orders as  $Pb > Cd > Ni > Co > Cr$ . The relative availability of both micronutrients and heavy metals were in the order  $Pb > Mn > Cd > Cu > Zn > Ni > Co > Fe > Cr$ .

Among the micronutrients Fe has least relative availability and among the heavy metals Cr has least relative availability, which shows that eventhough

high amounts of Fe and Cr are present in soil only very little amounts of them are available to plants.

### 5.3 EFFECT OF SEWAGE WATER IRRIGATION ON SOIL PROFILE PROPERTIES

The sand content in soil profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> which are irrigated with sewage water, at 0-15 cm, 15-30 cm and 30-45 cm ranged from 47.0 to 50.4; 40.7 to 49.3; and 36.3 to 50.9 with mean values of 49.06, 45.0 and 43.46 per cent respectively. Whereas the sand content of control profiles C<sub>1</sub> and C<sub>2</sub> at the same depths ranged from 69.6 to 76.8; 67.0 to 72.2 and 63.2 to 68.8 with mean values of 73.2, 69.6 and 66 per cent respectively (Table 13). The sand content in profile P<sub>1</sub> decreased upto 15-30 cm and thereafter increased, whereas in profiles P<sub>2</sub> and P<sub>3</sub> the sand content decreased with depth. In case of controls the sand content decreased as the depth increased. When compared to sewage irrigated soils, the controls had higher sand content at all depths.

The silt content in soil profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> which are irrigated with sewage water at 0-15 cm, 15-30 cm and 30-45 cm ranged from 18 to 24, 17 to 28 and 15 to 30 per cent with mean values of 21.33, 23.33 and 24.0 per cent respectively, whereas the silt content of controls C<sub>1</sub> and C<sub>2</sub> at the same depths are ranged from 12 to 16; 14 to 17; 17 to 20 with mean values of 14, 15.5 and 18.5 per cent respectively. The silt content in profile P<sub>1</sub> decreased slightly with depth whereas in P<sub>2</sub> and P<sub>3</sub> the silt content increased with depth. In control profiles C<sub>1</sub> and C<sub>2</sub> the silt content increased as the depth increased (Table 13). The increase in silt content in sewage

irrigated soils over controls at all the depths is due to irrigation with raw sewage water.

The clay per cent in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depth ranged from 28.2 to 31.6; 30 to 33.7 per cent 29.8 to 34.1 per cent with mean values of 29.6, 31.66 and 32.53 per cent whereas in control profiles C<sub>1</sub> and C<sub>2</sub> at the same depths, clay per cent ranged from 11.2 to 14.4; 13.8 to 16.0; 14.2 to 16.8 with means of 12.8, 14.9 and 15.5 per cent. In both sewage irrigated and control profiles, the clay content increased with depth. The silt and clay contents were more in the subsurface horizons which was due to illuviation of clay along with the sewage water moving down the profile. Similar observations were made by Singh and Singh (1994).

The mean pH of the sewage irrigated soil profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depth had the mean values 7.65, 7.83, and 8.08 respectively. The mean pH values of control profiles C<sub>1</sub> and C<sub>2</sub> at 0-15, 15-30 and 30-45 cm depths are 7.11, 7.39 and 7.64 respectively.

The pH of subsurface soils of both sewage irrigated and control profiles with in the profiles was higher as compared to the surface soils (Table 17). But when compared to control the sewage irrigated soil samples had higher pH at all the depths but the increase in pH is not significant (Table 17). The slight increase in pH in sewage fed profile soils over the control is due to irrigation with sewage water with alkaline pH (7.73). Similar trend was observed by Kuhad *et al.* (1989), Maiti *et al.* (1992) and Bhupalraj *et al.* (1997).

In the sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> the total soluble salt contents at 0-15, 15-30 and 30-45 cm ranged from 0.4 to 0.98, 0.33 to 0.72 and 0.35 to 0.68 dSm<sup>-1</sup> with the mean values of 0.74, 0.55 and 0.53 dSm<sup>-1</sup> respectively whereas total soluble salt contents of control profiles C<sub>1</sub> and C<sub>2</sub> at the same depths, ranged from 0.31 to 0.33 and 0.33 to 0.34 and 0.38 to 0.39 dSm<sup>-1</sup> with mean values of 0.320, 0.335 and 0.385 dSm<sup>-1</sup> respectively (Table 14). At all three depths of profiles the total soluble salt content of sewage irrigated soils was higher than that of control profiles, but the increase was significant over control only at 0-15 cm depth. The total soluble salt contents were lower in subsurface soils than surface soil in both sewage fed and normal soils which is due to the leaching of salts to lower depths. Azad *et al.* (1987), Maiti *et al.* (1992) and Sharma *et al.* (1994) also reported similar observations at different places.

The mean CEC values of profiles irrigated with sewage water P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depths were 25.86, 27.53 and 28.8 c mol (P<sup>+</sup>) kg<sup>-1</sup>. whereas the mean CEC values of controls at the same depths were 10.15, 10.93 and 11.35 c mol (P<sup>+</sup>) kg<sup>-1</sup>. The CEC in subsurface soils of both sewage irrigated and control profiles was more due to illuviation which results in high concentrations of exchangeable ions. Similar findings were reported by Singh *et al.* (1994).

The mean exchangeable sodium percentage of (ESP) values of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depths were 8.45, 8.7 and 9.03 whereas those of controls C<sub>1</sub> and C<sub>2</sub> at the same depths were 0.54, 0.69 and 0.78. There is slight increase in ESP as the depth increased

in both sewage irrigated and control profiles. Similar trend was also observed in exchangeable sodium content. At all the three depths there is significant increase in ESP in sewage irrigated profiles when compared to control profiles. This is due to the high CEC and exchangeable sodium in sewage irrigated soils over control.

The exchangeable  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  contents in soils of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depths had the mean values 14.3, 15.5, 16.6 and 6.9, 6.3, 6.36  $\mu\text{mol (P}^+) \text{ kg}^{-1}$ . Whereas those of control profiles C<sub>1</sub> and C<sub>2</sub> at the same depths were 6.55, 7.25, 7.3 and 2.5, 2.05, 1.35  $\mu\text{mol (P}^+) \text{ kg}^{-1}$  respectively. At all three depths the exchangeable calcium and magnesium contents of sewage fed soil profiles were significantly higher than the control profiles as depicted in Table 19. This might be due to the ability of both calcium and magnesium to form chelates with organic matter. However elevated levels of magnesium were found in the surface layers while calcium was concentrated at the bottom 30-45 cm layer. This is due to leaching of calcium to the sub surface layers. This may also be due to competition between calcium and magnesium for binding sites. These observations are in confirmation with the findings of Lakshmi Menon and Bhattacharya (1988).

The mean exchangeable  $\text{Na}^+$  and  $\text{K}^+$  contents in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15 cm, 15-30 and 30-45 cm depths were 2.41, 2.68, 2.83 and 0.47, 0.65, 0.75  $\mu\text{mol (P}^+) \text{ kg}^{-1}$  while those of controls at the same depths were 0.055, 0.075, 0.088 and 0.065, 0.085 and 0.119  $\mu\text{mol (P}^+) \text{ kg}^{-1}$  (Table 19). There is significant increase in exchangeable  $\text{Na}^+$

content in sewage irrigated profiles over control profile at all the three depths. This might be due continuous irrigation with sewage water containing high amount of sodium ( $226.8 \text{ mg l}^{-1}$ ). However the exchangeable sodium content in subsurface layers is slightly more than in the surface layer (0-15 cm). In control profiles there is no much variation in exchangeable  $\text{Na}^+$  content with depth. The exchangeable  $\text{K}^+$  content marginally increased with depth from 0-45 cm depth in both sewage irrigated and control profiles. Similar observations were reported by Maiti *et al.* (1992).

The mean organic carbon contents at 0-15, 15-30 cm, 30-45 cm of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> of Maize Research Station, Amberpet were 1.42, 0.78, 0.58 per cent respectively whereas the mean organic carbon contents of control profiles C<sub>1</sub> and C<sub>2</sub> at the same depths were 0.59, 0.39 and 0.35 per cent respectively (Table 17). Although the organic carbon content decreased in lower depths under both the conditions, sewage treated soils contained significantly more amount of organic carbon at 0-15 and 15-30 cm depth than in control soil. Similar observations were made by Maiti *et al.* (1992) at Calcutta and Bhupal Raj *et al.* (1997) at Hyderabad in sewage irrigated soils. Higher amount of organic carbon in the sewage water irrigated soils compared to control appears to be a consequence of the organic matter in sewage water.

The mean available nitrogen contents in sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depths were 286.2, 169.7, 129.4  $\text{kg ha}^{-1}$  respectively, whereas that of control profiles C<sub>1</sub> and C<sub>2</sub>, the mean available nitrogen contents at same depths were 121.84, 84.61 and

76.83 kg ha<sup>-1</sup> (Table 17). Mean available nitrogen content was higher in sewage irrigated profiles over control at all depths. However significant increase was observed only upto 15-30 cm soil layer. The available nitrogen content decreased with depth and followed the trend of organic carbon. Azad *et al.* (1987) and Maiti *et al.* (1992) also reported the same trend at different places. The high content of available N in surface layer is due to continuous irrigation with sewage water which contain higher amount of N.

The mean available phosphorus content of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15, 15-30 and 30-45 cm depths 101.73, 66.71 and 38.48 kg ha<sup>-1</sup> whereas in the control profiles C<sub>1</sub> and C<sub>2</sub> at the same depths were 22.8, 15.62 and 8.46 kg ha<sup>-1</sup>. Available phosphorus content in all layers was significantly higher in sewage irrigated soils than the control fields. However depth wise distribution of available phosphorus showed a declining trend. Similar findings were reported by Azad *et al.* (1987) and Maiti *et al.* (1992).

The mean available potassium contents of sewage irrigated profiles P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> at 0-15, 15-30 and 30-45 cm were 438.47, 610.84, 728.67 kg ha<sup>-1</sup> respectively whereas in the controls at the respective depths were 66.60, 91.55 and 123.35 kg ha<sup>-1</sup> respectively. When compared to control profiles. Significantly higher amounts of available potassium was observed in sewage fed soils compared to control at all depths. However the available potassium content decreased with the increase in depth in both sewage irrigated and control profiles. The higher content of available phosphorus and potassium in sewage irrigated profiles of all the depths over controls is due to

contamination of soils with sewage water rich in phosphorus and potassium. Maiti *et al.* (1992) reported that generally subsurface layers have higher amount of potassium when compared to surface layers.

The mean concentrations of water soluble ions  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$  at 0-15, 15-30, 30-45 depths were 206.2, 20.57, 146.06, 113.75; 142.06, 17.28, 97.5, 85.2 and 169.16, 11.17, 109.5, 70.77  $\text{mg kg}^{-1}$  respectively. Whereas the mean concentrations of water soluble ions Na, K,  $\text{SO}_4$ ,  $\text{Cl}^-$  in controls at the same depth were 9.0, 7.47, 4.29, 3.9; 7.15, 6.52, 2.67, 3.2; and 5.05, 3.1, 1.19, 2.05  $\text{mg kg}^{-1}$  respectively. In all the profiles irrigated with sewage water there is increase in water soluble ion content when compared to control at all the depths.  $\text{K}^+$  and  $\text{Cl}^-$  showed a declining trend with depth whereas  $\text{Na}^+$  and  $\text{SO}_4$  showed maximum accumulation at 0-15 cm then decreased upto 15-30 cm and again increased. Within the profile there is very slight variation in water soluble content with depth, which indicates that the entire profile (upto 45 cm) is saturated with water soluble ions may be due to continuous irrigation with sewage water over a long period of time.

The DTPA extractable and total zinc, copper, iron, manganese, lead, nickel, cobalt, cadmium and chromium contents were more in sewage irrigated profiles than the controls (Table 20 & 22). The increase in DTPA metals in sewage irrigated soils were significant over the control at all the depths except iron, manganese and cobalt at 30-45 cm depth (Table 21). Similarly increase in total metal contents followed the same significant trend at all depths except for Cu, Mn and Co at 30-45 cm depth (Table 23). The DTPA extractable and

total metals were more in surface soils when compared to subsoils (Table 21 and 23). This higher accumulation of metals in surface layer is due to the reduced mobility of metals into lower horizons. Specific adsorption of heavy metals by organic matter, manganese oxides, iron oxides, clay minerals humic acid fulvic acid etc., possibly have restricted their mobility into the deeper horizons. Organic compounds present in contaminated surface soils might have checked the mobility of metals into lower horizons as positive correlations existed between organic carbon content and DTPA extractable metal contents Jayabhaskaran and Sreeramulu (1996). Similar trend of decrease in heavy metal contents in soil with increase in depth was observed by Williams *et al.* (1980), Kuhad *et al.* (1989), Adhikar *et al.* (1993), Singh and Singh (1994) and Bhupal Raj *et al.* (1997).

#### 5.4 EFFECT OF SEWAGE WATER IRRIGATION ON MICRONUTRIENT AND HEAVY METAL CONCENTRATIONS IN PLANT PARTS

The effect of sewage irrigation on micronutrients and heavy metals in the shoot and edible parts is important because this is the first stage of entry of such constituents into the food chain.

The total Iron content of shoot of the Maize plant grown in sewage irrigated soil of Maize Research station, Amberpet, Hyderabad ranged from 50-120 mg kg<sup>-1</sup> with a mean value of 89.8 mg kg<sup>-1</sup>, which is in medium range of 60-150 mg kg<sup>-1</sup> as reported by Chapman (1975). The mean iron content in Maize seed ranged between 11-20 mg kg<sup>-1</sup> with a mean value of 15 mg kg<sup>-1</sup>. The iron content in the corn grain is much below than

that is present in the shoot (Table 24). The low iron content in the maize plant may be due to low relative availability of iron at the existing alkaline pH (Jeevan Rao, 1992). Irrigation with sewage water had very little effect on iron content in the corn grain. Similar results were reported by Kelling *et al.* (1977).

The manganese content in shoot of maize plants collected from sewage irrigated plots of Maize Research Station, Amberpet ranged from 39 to 136 mg kg<sup>-1</sup> with a mean value of 67.4 mg kg<sup>-1</sup>. The manganese content in maize shoots is within the range of 15-100 mg kg<sup>-1</sup> reported by Bowen (1966) and Allaway (1968). However in the grain the concentration ranged from 3.0 to 5.2 mg kg<sup>-1</sup> with a mean value of 4.1. The manganese contents of waste treated soils lead to toxing problems in acid soils Cottrell (1975), but since Amberpet soils are slightly alkaline soils toxicity problems have did not arise. The concentration in maize seed is very low due to less mobility of manganese metals into edible parts inspite of high concentrations in the soil.

Zinc content of maize shoots collected from Amberpet Maize Research station ranged from 16.1 to 40.15 mg kg<sup>-1</sup> with a mean value of 23.29 mg kg<sup>-1</sup> and it is within the range of 15-200 mg kg<sup>-1</sup> observed by Bowen (1966) and Allaway (1960) for agricultural crop plants. In corn grain, the concentration of Zn ranged from 4 to 9 mg kg<sup>-1</sup> with a mean value of 7 mg kg<sup>-1</sup>, which is very low when compared to that of shoot. Reddy *et al.* (1989) reported that soybean treated with sewage irrigation resulted in lower concentrations of Zn in seed from other tissues.

The concentration of copper in the plant shoots studied ranged between 2.7 and 8.2 mg kg<sup>-1</sup> with mean value of 6.79 mg kg<sup>-1</sup> and this is less than permissible safe range of 4-15 mg kg<sup>-1</sup> suggested by Bowen (1966) and Aalaway 1968. In grain the copper content ranged from 2.2 to 4.4 with a mean value of 3.2 which is low when compared to the amount of present in shoot. King *et al.* (1974 and 1976) reported that increased sewage addition to corn increased Cu content in plant but were below toxic level to crop and also observed that there is no effect of sewage water on Cu content in corn grain.

#### **Heavy metals**

The lead content in the shoots was more than that present in the grain. By and large, the contents of lead in plant shoots collected from sewage irrigated plots of Maize Research Station, Amberpet ranged from 1.9 to 3.5 mg kg<sup>-1</sup> with a mean value of 2.46 mg kg<sup>-1</sup> (Table 24), which are within the average range of 0.1 to 10 mg kg<sup>-1</sup> as suggested by Bowen (1966) and Allaway (1968). In grain the lead content ranged from 0.03 to 0.07 with a mean value of 0.05 which is low when compared to that present in the shoot.

The Nickel content in maize shoots collected from with sewage farm, Amberpet ranged from 0.45 to 0.76 mg kg<sup>-1</sup> with a mean value of 0.64 mg kg<sup>-1</sup> (Table 24) which is within the permissible average range 0.2 to 1.0 mg kg<sup>-1</sup> proposed by Bowan (1966) and Allaway (1968) for agricultural crops. Ethrington (1982) has proposed that Ni concentration in excess of 5 mg kg<sup>-1</sup> may pose pollution hazards. The observed range of

nickel is well below the toxic limit. The nickel content in the seed is in traces. Hence nickel content is not to an extent of causing pollution problems. The low uptake of Ni by the maize plant under alkaline conditions may be cause for low concentration in the plant. King *et al.* (1977) stated that there was no effect of sewage treatment on Ni levels in corn grain or straw.

Cobalt content in the maize shoots collected from sewage farm Amberpet, ranged between 0.005 to 0.092 mg kg<sup>-1</sup> with mean value of 0.026 mg kg<sup>-1</sup> which is well below the permissible range (0.05 to 0.5 mg kg<sup>-1</sup>) proposed by Bower (1966) and Allaway (1968) for agricultural crops. The cobalt content in corn grain is in traces. Hence it can be concluded that the plant shoots and edible parts contained acceptable content of cobalt.

The cadmium content of maize shoots collected from Maize Research Station, Amberpet ranged between traces to 0.195 mg kg<sup>-1</sup> with a mean value of 0.106 mg kg<sup>-1</sup> (Table 24). The cobalt concentrations of plant shoots studied were below the permissible concentration for agricultural crops (0.05 to 0.5 mg kg<sup>-1</sup>) suggested by Bowen (1966) and Allaway (1968). In grain the Cd content ranged between 0.04 to 0.09 with a mean value of 0.06 mg kg<sup>-1</sup>. There is no toxic accumulation of Cd in plant or seed even after continuous sewage irrigation. This is due to low uptake by plant.

The chromium concentration in the shoots of maize plants ranged between traces to 0.39 mg kg<sup>-1</sup> with a mean value of 0.152 mg kg<sup>-1</sup> (Table 24). Which is below 0.2 to 1.0 mg kg<sup>-1</sup> proposed by Bowen (1966) and Allaway (1968) for agricultural crops. The Cr content of edible portion (grain) ranged between 0.06-1.1 mg kg<sup>-1</sup> with a mean value of

0.08 mg kg<sup>-1</sup>. Key *et al.* (1979) reported that the Cd contents in corn due to sewage water application was below the toxic level to plants. The edible portions of plant species studied contained least chromium content and therefore do not pose any serious pollution problem, when these are consumed by animals or human beings.

It can be concluded from the present investigation, that the Mn, Zn, Cu, Fe, Pb, Ni, Co, Cd and Cr contents in shoot and seed were within the permissible limits and below the toxic range, hence have not posed any pollution problems in the food chain. However these may pose problem on long run.

It may be concluded from the present study that though the soil may contain high available elements, still plants have some selective mechanism which prevent the movement of these elements to the edible parts (Sreeramulu, 1994).



***SUMMARY***



## CHAPTER VI

### SUMMARY

An investigation was carried out to study the impact of sewage irrigation on soil chemical properties. The study was conducted on raw sewage water obtained from domestic wastes of Hyderabad city entering into Maize Research Station, Amberpet. This sewage water is not treated and is used for cultivation of crops over a long period of time. The sewage water was collected at fortnightly intervals from 22nd December 1997 to 9th March 1998. Their physical, physico-chemical and chemical properties were studied. Twenty five surface soil samples from plots irrigated with sewage water at random and ten surface samples from plots irrigated with normal water were collected. Simultaneously three profile samples from sewage treated plots and two profile samples from normal water irrigated plots (control) were collected, and were studied for various properties. Finally ten maize plant samples at random from sewage irrigated plots were collected at harvesting stage. Their micronutrient and heavy metal contents were determined.

The characterization of sewage water at Maize Research Station, Amberpet revealed its own distinct characteristics reflecting the kinds of pollutants that are entering into its stream from domestic as well as industrial units. The pH, soluble salt content, biological oxygen demand, dissolved oxygen, BOD, DO, TDS, TS were within the safe limits for irrigation purpose. However bicarbonates, sodium, COD, chlorides, sulphates, sodium absorption ratio were above the safe limits for irrigation purposes. The micronutrient contents except Mn were below the permissible limits for safe

irrigation. Among the heavy metal ions in the sewage water cobalt, nickel and lead were found to be within tolerable limits whereas cadmium and chromium were beyond permissible levels for crop irrigation. Thus there is a need to treat this raw sewage water to overcome the undesirable effects of its use for irrigation in the long run.

Continuous use of the sewage water for irrigation resulted in change of texture in comparison with control plots. Obviously, sewage water did bring silt and clay particles and as a result the treated plots registered increased silt and clay contents. Subsequently, this phenomenon is reflected in increased CEC of soils. The sewage water used for irrigation contained substantial amount of soluble salts and sodium and hence there was increase in the electrical conductivity and ESP.

Organic carbon, available nitrogen, phosphorus and potassium were higher in the soils that were treated with sewage water over the years. Though there has been continuous cropping on these soils. These parameters are still at higher side. This reflects in fact that this sewage water is a continuous source of higher amounts of N, P and K in comparison with normal water.

Both micronutrient and heavy metal contents in soils were higher due to their source from sewage water. However, their accumulation trend is not in direct relation with that of their content in sewage water. This is probably due to the fact that the metal ion contents in sewage water is not constant throughout as well over the years. Further, plant does have selected

mechanism to absorb and translocate these metals. Heavy toxic metals in general are poorly translocated and are usually accumulated in roots.

The study pertaining to characterisation of soil profiles indicated that within 45 cms, there has been variation in chemical parameters. DTPA extractable and total heavy metals and micronutrients and tended to accumulate in surface layers with restricted movement into lower depths. At the same time at any given depth their content in sewage fed profiles was higher than that of control profile. Similar trend of increased content of N, P, K, Ca, Mg, K, Na with depth in profiles was observed in sewage irrigated sites in comparison with that of irrigated with normal water.

The micronutrient and toxic heavy metals uptake by maize plant sample at harvest revealed that these metal ions are taken up by plant and in general are more than what is observed in normal plant. However, the plants analysed in the present study were normal, their contents are within the permissible limits, and did not exhibit any toxic effects or reduced yields.

## CONCLUSIONS

Based on these results, it was concluded that the sewage water used for crop irrigation at Maize Research Station contained useful available nutrients like N, P, K. It also contained substantial amounts of soluble salts like chlorides, sulphates, bicarbonates and sodium which are above the safe limit for irrigation. In addition to this the raw sewage water contained cadmium, chromium and manganese beyond the permissible levels for crop irrigation. The COD of the sewage water was also above the safe limit

for irrigation. Continuous irrigation with this raw sewage water over the years led to accumulation of soluble salts and heavy metals in soils. Though there is not much effect on maize plants at Maize Research Station, Amberpet further use of this raw sewage water continuously on long run may effect the crop growth in future. Thus there is a need for treatment of this raw sewage water to overcome the undesirable and harmful effects of its use for crop irrigation on long run.

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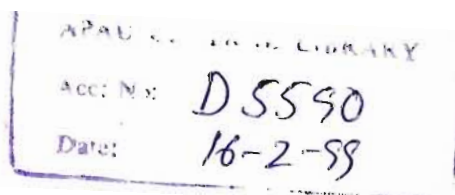
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