INFLUENCE OF PAPERBOARD MILL EFFLUENT ON VEGETABLE CROP AND SOIL ECOSYSTEM

By

S. PONMANI, B.Sc. (Ag.)
I.D.No: 06-610-008

DEPARTMENT OF ENVIRONMENTAL SCIENCES
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE - 641 003

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CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF PAPERBOARD MILL EFFLUENT ON VEGETABLE CROP AND SOIL ECOSYSTEM"** submitted in part fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCES** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Ms. S. PONMANI**, under my supervision and guidance and that no part of this thesis has been submitted for the award of any degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Place : Coimbatore
Date :

Dr. C.UDAYASOORIAN
Chairman

APPROVED BY

Chairman : Dr. C. UDAYASOORIAN

Members : Dr. G. BALASUBRAMANIAN

Dr. L. PUGALENDHI

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ABSTRACT

INFLUENCE OF PAPERBOARD MILL EFFLUENT ON VEGETABLE CROP AND SOIL ECOSYSTEM

BY

S. PONMANI

Degree **: Master of Science (Environmental Sciences)**

Chairman **: Dr. C.UDAYASOORIAN, Ph.D.,**
Professor and Head,
Department of Environmental Sciences
Tamil Nadu Agricultural University
Coimbatore - 641 003

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Reuse of industrial solid and liquid waste for agriculture is an alternate and effective method for cultivating crops in dry land tracts. Treated paper mill effluent irrigation provides nutrient enriched water supply for irrigation besides, it is a reliable and inexpensive system of wastewater treatment and disposal.

Field experiments were conducted at Indian Tobacco Company – Paperboard and Specialty Paper Division (ITC – PSPD), Unit : Kovai, located at Thekkampatti village, near Mettupalayam in Coimbatore District of Tamil Nadu, to determine the impact of treated paperboard mill effluent and solid wastes along with supplemental fertilizers on the yield and quality of vegetable crops *viz.,* chillies and brinjal. The experiments were conducted in a factorial randomized block design (FRBD) with three replications. The treatments consisted of biomanure, vermicompost, farmyard manure, fly ash either alone and in combination with 100 per cent recommended NPK.

Laboratory analysis of treated effluent released from ITC – PSPD revealed that the varying physical, chemical and biological properties were well with in the limits of state pollution control board norms.

Application of biomanure, vermicompost and fly ash under treated effluent irrigation had favorable effects on growth characters and yield attributes *viz.*, length, girth and weight of chillies and brinjal fruits. The experimental results revealed that yield of chillies and brinjal under treated effluent irrigation was significantly higher than well water irrigation. The treatment combination of biomanure @ 5 t ha^{-1} + vermicompost @ 3.5 t ha^{-1} + fly ash @ 5 t ha^{-1} + 100 % NPK performed better than rest of the treatments in both the crops. The yield increased being 20.90 per cent in chillies and 17.28 per cent in brinjal over control, which received 100 % NPK alone.

The quality of chillies and brinjal were not affected by irrigating the crops with treated paperboard mill effluent and incorporation of various solid wastes. The quality parameters *viz.*, ascorbic acid, capsaicin and oleoresin in chillies, and ascorbic acid and phenol in brinjal were not deteriorated due to the effluent irrigation and solid waste addition.

Among the solid wastes, application of fly ash, biomanure and vermicompost along with effluent irrigation had increased the soil organic carbon, available nutrients (N, P, K) and exchangeable cations (Ca, Mg, K and Na). The soil microbial population and enzyme activities such as urease, phosphatase and dehydrogenase were higher under effluent irrigation, leads to increased soil health and crop growth. The harmful effects of continuous effluent irrigation could be ameliorated due to addition of amendments like biomanure, vermicompost and fly ash.

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ABBREVIATIONS USED

%	:	Per cent
BOD	:	Biological Oxygen Demand
CEC	:	Cation Exchange Capacity
ESP	:	Exchangeable Sodium Per cent
CD (0.05)	:	Critical Difference
CFU	:	Colony forming units
cm	:	Centi metre
cmol (p^+) kg^{-1}	:	Centi mole per kilogram
COD	:	Chemical Oxygen Demand
DAT	:	Days after transplanting
dS m^{-1}	:	Deci Siemens per metre
EC	:	Electrical Conductivity
Fig.	:	Figure
kg ha^{-1}	:	kilogram per hectare
Mg m^{-3}	:	Mega gram per meter cube
mg L^{-1}	:	milli gram per liter
NS	:	Non – Significant
OC	:	Organic carbon
pH	:	Hydrogen ion concentration
SEd	:	Standard Error of deviation
h^{-1}	:	per hour
t ha^{-1}	:	tonne per hectare
@	:	at the rate of
µg g^{-1}	:	Micro gram per gram
TPF	:	Triphenyl formazan
PNPP	:	Para-nitrophenol phosphate

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CHAPTER I

INTRODUCTION

Growing literacy and high standard of living have increased the paper consumption resulting in more production of paper and wastewater. Pulp and paper industry is one of the largest consumers of plant and water resourses, which releases significant amount of effluents in nearby areas. Moreover it affects the physical environment of the soil. There are about 600 paper mills in the country with an annual installed capacity of 8.5 million tonnes of paper. The average quantity of water consumed for each tonne of paper produced is about 300 m^3 and this amount reappears as effluent causing wide spread environmental pollution (Hazarika *et al.,* 2007).

In Tamil Nadu, there are about 31 units with an installed capacity of 0.64 million tonnes per annum. The Indian Tobacco Company - Paperboards and Specialty Paper Division (ITC-PSPD) located at the foothills of Western Ghats at Thekkampatti village, Mettupalayam Taluk, Coimbatore, Tamil Nadu is a pioneer industry in making of fine quality duplex paperboard from waste papers. The production capacity of the factory is around 280-300 metric tonnes of duplex board per day and it consumes around 2500 -3500 m^3 of water. The factory discharges around 2100 - 2600 m^3 of effluent, 15 – 20 tonnes of sludge and 20 - 25 tonnes of fly ash per day. The effluent is properly treated in modernized Effluent Treatment Plant (ETP) and is being completely utilized for irrigation, in about 206 acres of virgin land owned by the factory.

Reuse of wastewater in agriculture is expected to increase dramatically in future as fresh water resource has become increasing scarce and expensive as ground water is being depleted rapidly. Application of effluent on land offers a promising alternative as irrigation water and source of plant nutrients while offering solution to the disposal problems. However, effluents of some industries have useful characteristics and have the potential to improve soil productivity (Kansal, 1994). The pH, EC, organic carbon, CEC and exchangeable cationic activities were improved in effluent irrigated soils over the years, without any deterioration on crop quality (Palanisami and Sreeramulu, 1994; Udayasoorian *et al.,* 2004; Prathiba, 2005; Jayanthi, 2007).

The present consumption of vegetable per capita per day in India is 135 g against the requirement of 285 g per day. It indicates the necessesity to raise the production of vegetables which can be achieved by linking more land under vegetable cultivation and increasing productivity of the vegetables as well. Generally, vegetable crops are sensitive to soil pollution and they are the best indicators of hazardous chemicals.

Chillies (*Capsium annum L.*) are cultivated in all the states and union territories of the country. The area under cultivation is estimated to be around 8 lakh hectares. The total production stands at around 84 lakh metric tonnes (Seasonal Crop Report, 2004).

India is the centre of origin for brinjal or eggplant. Brinjal has been cultivated in India for the last 4000 years. It is grown all over the country, year-round and is one of the most popular vegetables of India. The area under cultivation is estimated to be around 5 lakh hectares. The total production stands at around 82 lakh metric tonnes (AICRP, 2006). The main growing areas are in the states of Andhra Pradesh, Bihar, Karnataka, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal.

From the extensive literature survey conducted in handling the environmental pollutants, it was observed that it is very essential to plan for cost effective and eco friendly techniques for decontamination/utilization of treated paperboard effluent. In this investigation vegetable crops like chillies and brinjal are used as test crops to assess the impact of treated paperboard mill effluent irrigation, because the farmers in and around the ITC (PSPD) are mainly cultivating these vegetables due to their higher net return. Hence the present investigation has been taken up with the following objectives:

1. Characterization of treated paperboard mill effluent for its physical and biochemical properties.

2. Assessing the impact of treated paperboard mill effluent irrigation on yield and quality of brinjal and chillies.

3. Evaluating the impact of amendments along with treated effluent irrigation on soil health.

CHAPTER II

REVIEW OF LITERATURE

Many industries produce large volume of effluents requiring proper disposal. Lack of suitable technologies and disposal facilities is a major hindrance to industrial expansion. The recycling options of industrial effluents includes land application, use in irrigation, forestry, application to constructed wetlands or artificial marshlands. Application of effluent on land offers promising alternative as irrigation water and source of plant nutrients while offering solution to disposal problems.

Agro industrial wastes, being organic in nature, can be used in agriculture to increase the organic matter content of the soils. Apart from their nutritional value, these organic materials improve the physico-chemical properties of the soils and thereby increase the fertility and productivity of soils (Naphade *et al*., 1998).

The relevant literature regarding utilization of treated effluent for crop production and its impact on crop growth, yield, quality of crop produce and soil is reviewed in this chapter.

2.1. Characteristics of effluent from paper and board mill

2.2. Characteristics of solid waste from paper and board mill

2.3. Effect of solid wastes on soil quality

2.4. Effect of effluent irrigation on soil quality

2.5. Effect of effluent and solid wastes on field and horticultural crops

2.6. Impact of amendments application on soil and crops

2.1. CHARACTERISTICS OF EFFLUENT FROM PAPER AND BOARD MILL

2.1.1. Physico-chemical properties

The characteristics of the pulp and paper mill effluent vary depending on its sources *viz.*, debarking wastewater, mechanical pulping wastewater, kraft black liquor, spent sulfite liquor, bleaching wastewater and paper mill wastewater (Rintala and Pubakka, 1994). The pulp and paper mill effluent was normally dark brown in colour

(Alfred, 1998; Srinivasachari *et al.,* 1999). The disagreeable phenolic odour was observed, it was due to presence of hydrogen sulphides in the effluent, which was evident from the higher sulphate content of the effluent samples (Srinivasachari *et al*., 1999).

The presence of colouring matter in the mill waste has very serious impact on the aesthetic value of the consumer (Upadhyaya and Singh, 1991). The colour of the raw paper mill effluent was normally dark brown in colour (Hameed, 1997; Alfred, 1998; Srinivasachari *et al*., 1999). Lignin and its derivatives impart an offensive colour to the water, which is not only aesthetically unacceptable, but also inhibit the natural process of photosynthesis in the stream due to absorbance of sunlight (Murugesan and Kalaichelvan, 2003).

Francis *et al*. (1999) stated that the pulp mill effluent contained appreciable amount of suspended solids (220 – 774 mg L^{-1}) and total soluble salts of 780 – 1818 mg L^{-1}. The per cent sodium content of the treated effluent was around 40 and effluent had BOD of 5.2 to 10.0 mg L^{-1} according to Udayasoorian *et al.* (1999b). The diluted effluent of the paper mill had slightly alkaline pH, high BOD, COD and EC with appropriate quantities of Cl, SO_4 and HCO_3 of Ca, Mg, and Na and varying amount of micronutrients (Srinivasachari *et al.,* 1999; Udayasoorian *et al*., 1999c). The BOD and COD of treated paper mill effluent were around 5.2 - 10.0 and 420.0 mg L^{-1}, respectively (Hameed, 1997; Malathi, 2001).

The treated pulp and paper mill effluent had dissolved oxygen of 3.40 mg L^{-1} (Prabu, 2003). Srinivasachari *et al.* (2000) found that the effluent had higher levels of N, P and K. Paper mill effluent was characterized by comparatively low BOD (68 mg L^{-1}), suspended solids (85 mg L^{-1}), COD (258 mg L^{-1}), plant nutrients (N, P and K 50.0, 1.50 and 74.0 mg L^{-1}, respectively) and Na content of 546 mg L^{-1} (Chatterjee *et al.*, 2003). The treated paper mill effluent had considerable amount of NH_4-N according to Hameed and Udayasoorian (1999).

The effluent from paper mill was rich in organic carbon (OC). Due to the presence of varying quantities of suspended and dissolved solids in the effluent, the OC content ranged from 0.82 to 0.87 per cent (Srinivasachari *et al*., 1998a).

The chloride content of treated effluent varied from 207.4 to 358.1 mg L^{-1} and it was well within the limit (600 mg L^{-1}) of the State Pollution Control Board (SPCB)

(Udayasoorian *et al*., 1999b). The pulp mill wastewater had high concentration of soluble Na (21.5 cmol L^{-1}) as compared to Ca (2.4 cmol L^{-1}). The effluent samples also contained various amount of micronutrients like Zn, Cu, Fe and Mn (Srinivasachari *et al.,* 1998a). The wastewater from the pulp and paper mill effluent had various toxic substances. The effluent contained methyl mercaptan and pentachlorophenol, which were highly toxic (Udayasoorian and Jothimani, 1998).

2.1.2. Biological properties

The combined effluent from pulp and paper industry had considerable population of bacteria, actinomycetes, fungi, azotobacter and yeast. Srinivasachari *et al*. (1999) observed that the paper mill effluent had low population of actinomycetes and fungi and appreciable number of bacteria. The number of yeasts in the effluent reached 10 lakh cells L^{-1} and *Rhodotrorula* sp. was commonly isolated from most of the ascoporogenus yeast that was found as *Hansenula oxpicchia* (Prabu, 2003). Yu and Mohn (2001) investigated bacterial diversity and community structure of pulp mill effluent and reported that temporal differences in community structure were greater than spatial differences.

Paper mill effluent can be used for bioproduction of nitrogen fixing blue green algae – *Scytonema schmidlei, Anabaena cylindrical, Clotheix marchica, Gloeatrichia echinulata* and high protein containing *Spirulina platensis* (Patnaik *et al.*, 1995).

2.2. CHARACTERISTICS OF SOLID WASTE FROM PAPER AND BOARD MILL

The quantities and characteristics of solid wastes generated from pulp and paper factory are highly dependent on raw materials, processes and process conditions used in the mill (Rintala and Puhakka, 1994). According to them the principle organic constituents in pulp and paper mill primary sludges include cellulose, hemicellulose, lignin and other compontents of wood fibre, process chemicals and compounds, produced during pulping.

The production of bleached kraft pulp normally generates several inorganic residues, including primary clarifier sludge and brown stock screening rejects (Springer, 1993; Sherman, 1995). Aerobic secondary treatment of effluents also produces a considerable amount of residues such as the microbial biomass (Graves and Joyce, 1994).

Elvira *et al*. (1996) reported that solid paper pulp mill sludge has a total solid content of 189 g kg^{-1}, pH of 9.2, total organic carbon content of 541 g kg^{-1}, total kjeldahl nitrogen of 18.5 g kg^{-1} with a C/N ratio of 17:6. Land application of solid waste provides an effective and environmentally acceptable option of waste disposal, which also recycles valuable nutrients into the soil plant system (Jayamani and Devarajan, 1995).

2.2.1. Nutrient content of solid wastes

Primary sludge consisted of organic matter mainly in the form of cellulose, wood fibre and has low N content (0.10 to 0.25 per cent) on dry weight basis. For biological treatment, N and P are essential and are added to secondary treatment process resulting in higher N (3.0 to 4.0 per cent) and moderate P (0.1 to 0.3 per cent) in secondary sludge (Bellamy *et al.,* 1995). Linear increase in important soil nutrients like nitrogen, phosphorous and potash with the application of sludge after one or two growing seasons was observed by Fresquez *et al.* (1990).

The bagasse pith contained the lowest nutrients of N, P, K, Ca and Mg *viz.*, 0.91, 0.69, 0.98, 0.95 and 0.28 per cent, respectively with wide carbon to nitrogen ratio and very low level of micronutrients (Sandana, 1995). Mixing bagasse pith with activated sludge and effluent treatment plant (ETP) sludge in the ratio of 2:1:1 produced better quality compost. Among the amendments, sludge had comparatively higher plant nutrients than FYM, while fly ash and bagasse pith were low in nutrients. The TNPL lime sludge had higher concentration of Ca and Mg recording 8.60 and 11.0 per cent, respectively but essential nutrient states was very low (Hameed, 1997).

Kannan and Oblisami (1990 a) had reported that paper mill sludge was found to have a pH of 7.91 and ash content of 15.30 per cent. And also it contains organic carbon (45.30 per cent), total nitrogen (0.31 per cent), available phosphorus (0.11 per cent), potassium (0.29 per cent), calcium (213 mg kg^{-1}), magnesium (85 mg kg^{-1}), lignin (16.10 per cent) and cellulose (23.40 per cent) as major constitutes.

Fly ash contains many minute glasses like particles with alkaline pH and having an EC of 1.40 dS m^{-1} (Kannapiran *et al.*, 1997). The N, P and organic carbon content were very meagre and had considerable amount of K, Ca and Mg. Presence of various elements such as P, K, Ca, Mg, S and micronutrients in the fly ash made it a good source of plant nutrients (Kumar *et al.,* 1998; Selvakumari *et al.,* 1999). Fly ash was found to be poor in available N and P, but it contained sufficient amount of potash (Kannapiran, 1995). The presence of P and K in fly ash and the fineness of the material made its addition to acid soil to benefit crop growth by increasing the availability of nutrients (Lal *et al.,* 1996).

2.2.2. Toxic constituents of solid waste

Paper mill sludge was rich in organic chemicals *viz.*, phenolics (0.067 – 4.30 mg kg^{-1}), phthalate esters (<2 –12 mg kg^{-1}), benzene (<0.2 mg kg^{-1}), toluene (<0.4 –2.3 mg kg^{-1}), xylene (0.2 mg kg^{-1}) and pentachlorobenzene (0.01 – 0.4 mg kg^{-1}) (Bellamy *et al.,* 1995).

The heavy metals in the soil were subjected to various chemical and physical interactions with organic matter, hydrous oxides of iron and manganese. Concentration of heavy metals like lead, zinc, chromium, nickel and selenium was higher than cadmium in sludge (Srikanth *et al.,* 1992). Bhoyar *et al.* (1992) observed that solid waste might affect the soil concentration of metals and toxic constituents.

2.3. EFFECT OF SOLID WASTE ON SOIL QUALITY

2.3.1. Physical properties

Patil *et al.* (2003) observed that bulk density, porosity, infiltration rate and water holding capacity of soil were significantly influenced due to application of different levels of fly ash and FYM. Due to presence of higher organic content in paper mill solid waste it had a favourable effect on soil physical conditions. Application of paper mill sludge to mine spoiled areas increased the soil aggregation, which in turn enhanced the stability, water retention and served as a nutrient reservoir (Feagley *et al.,* 1994).

Simard (2001) achieved an increase in soil-water holding capacity of silt loam. Improved soil structure and total porosity due to paper mill sludge application was observed by Sun and Lie (1992).Yingming and Corey (1993) observed that sludge application could alter the bulk density of soils, especially when heavy loadings were employed.

2.3.2. Chemical properties

Aitken *et al.* (1998) reported that the use of solid waste in crop lands increased organic carbon in silt loam and clay loam soils. Zibiliske (1998) reported an increase in organic carbon of loamy soils after application of solid waste. Sandhya and Ramaswami (1995) reported that solid waste had high concentration of organic matter (68 to 76 per cent) containing mostly cellulose (60 to 67 per cent) and inorganic materials (20 to 31 per cent).

Soil pH and organic matter content were increased with addition of paper mill sludge (Palaniswami and Sree Ramulu, 1994). On the contrary, a reduction in soil pH due to pressmud and ETP sludge addition was observed by Prabu (2003). Selvakumari *et al.* (1999) observed an increase in pH when fly ash was used in normal soil. Mixing of fly ash in soil does not affect the concentration of soil solute. However, Patil *et al.* (2003) observed an increase in EC of soil after mixing with fly ash.

Continuous use of paper mill sludge over a period of 15 years to sandy soil increase the soil EC, exchangeable Na, Ca, Mg and K, available P, K, Fe, Mn, Zn and Cu (Palaniswami and Sree Ramulu, 1994). Rodella *et al.* (1995) reported that paper mill sludge resulted in increase of soil CEC. The improvement in the available P status of the soil was noticed in fly ash applied soil (Sahoo and Kar, 1998).

Satishkumar (2002) inferred that application of biosludge @ 12.5 t ha^{-1} both in effluent irrigated and well water irrigated plots recorded significant increase in the organic carbon content and soil available nitrogen.

2.3.3. Biological properties

Application of decomposed paper mill waste at the rate of 5 to 10 t ha^{-1}, improved the biological activity (Udayasoorian *et al.,* 1999b). Sludge ameliorants rapidly increased the activity of micro organisms resulting in increased availability of plant nutrients and provided favourable environment for plant growth. IIyaltdinov *et al.* (1990) reported that application of decomposed paper mill waste at the rate of 10-20 t ha^{-1} improved the biological activity. Dhevagi *et al.* (2003) stated that, increased level of soil cellulase activity under paper mill effluent irrigation along with different amendments.

Combined application of fly ash with sewage sludge increased the microbial load, the actinomycetes and fungal counts in the soil typically decreased with increased in ash content (Pichtel and Hayes, 1990).

2.4. EFFECT OF EFFLUENT ON SOIL QUALITY

2.4.1. Physico-chemical properties

The pulp and paper mills have attempted to dispose lignin rich colored effluent through waterways on lands. The soil has the capacity to retain the lignin and the coloring matter (Palaniswami and Sree Ramulu, 1994). Srinivasachari *et al.* (1998a) reported that the sodium in effluent have accumulated over the years thereby increasing the soil pH. Irrigation with undiluted paper and pulp industry effluent had led to increased soil pH (Dutta, 1999; Dhevagi *et al.,* 2000). Phukan and Bhattacharyya (2003) also reported that the paper mill effluent irrigation turned the soil pH towards alkalinity. The soil pH shifted towards alkaline when irrigated with undiluted paper factory effluent (Udayasoorian *et al*., 1999a; Srinivasachari *et al*., 2000; Prasanthrajan *et al*., 2004).

Continuous irrigation with treated pulp and paper mill effluent resulted in increased soluble salt in sandy loam soil (Udayasoorian *et al*., 1999b). The increase in soil EC was observed in all the seasons due to effluent irrigation and it has been attributed to the addition of considerable quantity of dissolved salts through the effluent (Srinivasachari *et al.,* 2000). Srinivasachari *et al*. (2000) and Udayasoorian and Prabu (2003) reported an increase in soil EC due to paper mill effluent irrigation. The analysis of soil samples reveals that continuous use of the paper mill effluent has increased the pH, EC and Na content of soil (Narwal *et al.*, 2006).

The higher CEC and exchangeable cations in soil irrigated with effluent could be ascribed to the accumulation of cations present in the effluent and higher organic content due to continuous irrigation with effluent (Srinivasachari *et al.*, 1998b). More than 17 years of irrigation in a heavy textured acidic soil with paper mill effluent has higher level of bases and chloride which significantly increased the soil pH, soil salinity, sodicity, base saturation and CEC (Hazarika *et al.,* 2007). Nila Rekha *et al*. (1996) reported that the soil organic matter content increased due to continuous effluent irrigation. Increased soil organic matter content was observed due to paperboard mill effluent irrigation (Elayarajan *et al*., 2003; Prasanthrajan *et al*., 2004).

The treated effluent irrigation increased the value of soil NPK (Udayasoorian *et al*., 1999b). Undiluted effluent irrigation increased the available N and K content of soil whereas, decreased the available P (Srinivasachari *et al*., 1998a). Chatterjee *et al.* (2003) reported that N, P and K availability and organic carbon content were enhanced by effluent irrigation, though the EC and pH of the soil increased.

Singh and Room Singh (2005) reported more diluted effluent (25 per cent or 50 per cent) improved the availability of P and S, however in long run it too may result in build up of soil salinity. Hameed and Udayasoorian (1999) stated that the exchangeable cations of soil increased as the duration of effluent irrigation advanced. There was an increase in exchangeable Na concentration of the soil under treated effluent irrigation at harvest stage of crop growth, the sodium adsorption ratio (SAR) of the soil also increased due to continuous effluent irrigation (Alfred, 1998). In contrast, Ca and Mg increased in soil rather than Na due to continuous irrigation with effluent (Honora *et al*., 1999). The DTPA extractable Zn, Cu, Fe and Mn largely accumulated in the upper 15 cm soil region and the extent of their accumulation was increased with increased time of application (Srinivasachari *et al*., 2000).

2.4.2. Biological properties

The increase in organic matter content of the soil due to effluent irrigation accelerated the microbial activity and inturn accelerated the substrate decomposition with the release of carbon dioxide (Kannan and Oblisami, 1990b). Diluted effluent was found to increase the microbial population and fertility of soil (Chauhan and Kaur, 1991). Higher population of bacteria, fungi and actinomycetes were recorded in paperboard mill effluent irrigated soil (Prasanthrajan, 2001; Elayarajan, 2002).

Kumar *et al.* (2000) showed that the minimum microbial characteristics were recorded in normal soil at 25 per cent paper mill effluent concentration while the maximum values were recorded in soil mixed clay at 100 per cent effluent irrigation.

Palaniswami and Sree Ramulu (1994) reported that urease and alkaline phosphatase activity were observed to be maximum in 15 years effluent irrigated soil. Oblisami and Palaniswami (1991) reported that paper factory irrigation resulted in an increases in soil amylase, invertase, cellulose, dehydrogenase and phosphatase activity which directly proportional to the period of effluent irrigation to the soil.

The continuous effluent irrigation for sugarcane crop did not have any adverse effect on the soil microflora (Anita *et al*., 1997). The effluent irrigation to *Eucalyptus* seedlings enhanced the population of rhizosphere soil bacteria, fungi and actinomycetes (Hameed, 1997). Elayarajan and Murugesa Boopathi (2006) reported that higher microbial population recorded in the effluent irrigated soil of maize crop.

2.5. EFFECT OF EFFLUENT AND SOLID WASTES ON CROPS

2.5.1. Effect of effluent and solid wastes on field crops

Anoop (2002) reported that diluted pulp mill effluent irrigation in wheat (*Triticum aestivum* var UP-2329) increased the chlorophyll content, plant height, shoot and root biomass, grain yield, protein, carbohydrate and lipid contents in wheat grains, while undiluted effluent caused inhibition in plant growth resulting in a sharp decline of yield. The grain yield increase was around 20 to 25 per cent under treated paper mill effluent irrigation than that of well water irrigation.

Oil content of groundnut crop was increased due to treated TNPL effluent irrigation than well water. The crude protein content of groundnut was increased due to TNPL effluent irrigation (Udayasoorian *et al.,* 2004) and also reported the treated TNPL effluent irrigation resulted in higher pod yield than well water irrigation.

Alfred (1998) recorded higher grain yield (6.88 t ha^{-1}) in pressmud amended soil with effluent irrigation. Udayasoorian *et al.* (1999a) concluded that the yield of maize and oil seed crops were higher in the paper mill effluent irrigated fields. Rice yield was higher under pulp and paper mill effluent irrigation compared to well water. Among the three varieties tested IR20 and white ponni performed better than ADT 36.The effluent irrigation did not affect the grain yield of rice (Srinivasachari *et al.,* 1998b).

The soil amendments had favorable effects on the P and K uptake of rice in acid soil. The use of 50 per cent diluted classified effluent was found superior to raw effluent irrigation more particularly in neutral soil (Velu *et al.*, 1998). The adverse effects of effluent from paper factory could be alleviated by resorting to the application of N, P and K along with organic and inorganic amendments such as pressmud, FYM and gypsum (Pushpavalli, 1990).

Mahar *et al.* (2008) reported that application of pressmud @ 25 t ha^{-1} on sugarcane recorded higher number of tillers and sugar recovery after inorganic fertilizer application @ 225- 112-168 kg ha^{-1} of NPK. Enriched pressmud @ 10 t ha^{-1}, increased the number of millable canes in sugarcane (Rakkiyappan *et al.,* 1999). The increase in brix, pol per cent, purity and CCS of sugarcane juice were 1.03, 0.97, 0.26 and 0.43 units, respectively under effluent irrigation than under well water irrigation. An increase of 0.43 per cent of commercial cane sugar was recorded under effluent irrigation (Suguna Devakumari, 2005).

The increase in fodder yield in cumbu napier hybrid due to effluent irrigation over well water was 39.32 per cent followed by guinea grass (38.68 per cent), congo signal (27.40 per cent) and the least in para grass (16.50 per cent) (Ponniah and Ramaswamy, 1999). Sewage water irrigation increased the green fodder yield and dry fodder yield in bajra napier hybrid grass (Malarvizhi and Rajamannar, 2001).

2.5.2. Effect of effluent and solid wastes on horticultural crops

Laboratory germination studies were conducted to determine the effect of raw and treated paper mill effluents on bhendi, brinjal, chillies, tomato, amaranthus, bitter gourd, beetroot and moringa revealed that seed germination percentage, shoot length and vigor index were higher in treated effluent than the raw effluent (Udayasoorian, *et al.,* 2003). The quality traits of flowers *viz.,* vase life, essential oil and xanthophylls content were increased under effluent irrigation (Arul, 2002).

Yield parameters of tomato *viz.*, number of fruiting clusters, fruit weight and fruit yield were higher in treatments amended with bio-earth, pressmud and FYM along with treated paper mill effluent irrigation (Sandana, 1995; Udayasoorian *et al.,* 1999a). Tomato fruit quality parameters such as total solids content, ascorbic acid and NPK content were more in bioearth amended treatment followed by pressmud and FYM amended treatment along with paper mill effluent irrigation (Sandana, 1995).

The yield of bhendi (var. PKM 7) was reduced with sugar factory effluent. But 75 per cent dilution of effluent recorded a yield of 12.5 t ha^{-1} (Rathinasamy and Narashimhan, 1998). Rao and Rao (1992) reported that irrigating tobacco and chillies with effluent water lead to reduced yield. *Amaranthus tricolor* and *Brassica chinensis* gave the highest productivity in soils treated with pig manure (Wong, 1990).

Total and non-reducing sugars, ash, K, Na, Mn and Cu were also increased under paperboard mill effluent fertigation in banana (Prabakaran, 2003) and also reported that in banana the finger quality parameters like finger length, circumference, weight pulp and peel etc., were increased with reduced pulp peel ratio due to effluent fertigation with 75 per cent N, P and K while basin irrigation to effluent reduced the above quality parameters (Prabakaran, 2003).

The crude protein content of bhendi and amaranthus was more in paper mill effluent irrigated crop than river water irrigated crops. The treated effluent had improved the P content in amaranthus; addition of paper mill ETP sludge along with effluent irrigation had a profound influence in improving the quality traits of bhendi and amaranthus (Malathi, 2001).

The quality of radish and onion were not affected by irrigating the crops with treated effluent and by incorporation of various solid wastes .The quality parameters like vitamin C, total acidity, calcium and potassium in radish and vitamin C, total acidity, calcium, pyruvic acid and total soluble solids in onion were not deteriorated due to the effluent irrigation and solid waste addition (Prathiba, 2005).

The chlorophyll (9.89 mg g^{-1}) and carotenoid content (0.53 mg g^{-1}) of chillies were increased due to effluent irrigation (Sheela and Deepa Peethambaram, 2007). Malathi (2001) reported that the germination per cent, root length, shoot length and vigour index of brinjal and chillies were better in treated effluent as compared to raw effluent.

Growth and marketable yield of flower crops *viz.*, gundumalli (*Jasminum sambac*), jathimalli (*Jasminum grandiflorum*), tuberose (*Polianthus tuberosa*) and nerium (*Nerium oleander*) were significantly higher with the 50 per cent diluted effluent followed by raw effluent than well water irrigation (Mahimairaja *et al.*, 1999). Treated food industry effluent and composted sludge promoted growth and yield of ornamental plants like *Tagetes patula* (French marigold), *Tagetes erecta* (African marigold), *Zinnia elegans* and *Malcolmia maritima*. The composted sludge along with sand in the ratio of 2:1 produced good quality cut flowers (Tolay *et al*., 2000).

The potential use of combined primary and secondary dewatered paper mill sludge compost was assessed for its suitability as potting media in virginia for marigold production. Compost with N produced large size plant with higher number of flowers than commercial potting media (Evanylo and Daniels, 1999). The chrysanthemum grown in soils added with saw dust and coal ash produced plants with high chlorophyll content, yield and increased the flower diameter (Zhanojinzhou *et al*., 1999).

Application of municipal solid waste compost in combination with inorganic fertilizers effectively increased plant height, leaf number, number of branches and flower yield compared to normal farmers practice in China aster and this municipal solid waste compost can be applied as organic manure to the flower crops (Sreenivas and Gowda, 1999).

The treated urban wastewater utilized for the marigold production has increased the marketable flower yield and removed considerable amount of inorganic pollutants from the field (Mizuta *et al.,* 1998). The treated sewage effluent had considerable amount of N, P and organic matter, which enhanced the growth of flowers *viz.,* marigold and English daisy (Abe and Ozaki, 2001). The flower character of celosia *viz.,* flower diameter flower weight and number of flowers were increased under treated paperboard mill effluent irrigation than well water irrigation (Jayanthi, 2007).

2.6. IMPACT OF AMENDMENTS APPLICATION ON SOIL AND CROPS

The quality and value of organic soil amendments are often measured in terms of their contributions to nutrient supplies and soil fertility. However, they can also have significant effect on the microbiological and chemical properties of the soil, which are indirectly responsible for supporting crop growth. In particular, the microbiological properties of soil can influence soil organic matter decomposition and soil enzymatic activities (Nannipieri *et al.,* 1990).

2.6.1. Impact of FYM on soil and crops

Susan John, (2005) found that FYM contains 2.34 per cent N, 0.68 per cent P, 31 ppm of Fe, 145 ppm of Mn, 39 ppm of Zn and 3.5 ppm of Cu. Nitrogen content of 1.19 per cent, phosphorus of 0.11 per cent and potassium of 1.03 was found in FYM. Meena *et al.* (2007) reported that FYM had 0.46 per cent N, 0.18 per cent P and 1.32 per cent K.

Farmyard manure has a beneficial acidifying effect on the sodicity of the soil both through the action of organic acids formed during its breakdown, and because the Ca +

Mg contained in farmyard manure replaces the Na from the exchange complex. Therefore, addition of organic materials would help the reclamation process by reducing pH and exchangeable sodium in soils. Because of small and less active microflora in saline soils, mineralisation of organic nutrient fractions is comparatively low. So the retention of nutrients in organic forms for longer periods will guard against their leaching and other losses (Minhas, 1996).

Panda (1995) and Meelu (1996) reported that application of FYM not only improved the physico-chemical properties of the soil like bulk density, water holding capacity and organic carbon content but also had little effect on residual phosphorous and potassium in the soil. Green manuring and FYM incorporation increased the water soluble aggregates, infiltration rate and reduced the bulk density of the soil and helped to improve the physical conditions. Application of FYM and vermicompost decreased the bulk density and increased the water holding capacity than NPK application (Maheswarappa *et al.,* 1999).

The beneficial effects of FYM on various physico – chemical properties of soil and to sustain high levels of yield were reported by Sudhakar (2000). The FYM seems to act directly by increasing the crop yield either by accelerating the respiratory process through cell permeability or by hormone growth action. It supplies nitrogen, phosphorous and sulphur in available forms to the plants through physiological decomposition. Indirectly, it improves the physical properties of soil such as aggregation, aeration, permeability and water holding capacity (Chandramohan, 2002).

Dhiman *et al.* (1998) reported that application of FYM @ 10 t ha^{-1} + 100 per cent recommended N increased the organic carbon content. Incorporation of organic manure in the form of FYM and crop residue increased the organic matter content of the soil (Thakur *et al.,* 1999). Maheswarappa *et al.* (1999) observed that the organic carbon content was increased to a greater extent at 0 – 25 cm depth with FYM and vermicompost application than the other organic sources

Sudhakar (2000) observed that application of FYM @ 12.5 t ha^{-1} increased the available phosphorous content in paddy field. Khatik and Dikshik (2001) also reported higher available K due to the application of 10 t ha^{-1} of FYM or compost. Bokhtiar and

Sakurai (2005) reported that the addition of FYM (or) pressmud @ 15 t ha^{-1} and green manure (*Crotalaria juncea*) increased the organic carbon, total N and available P, K, S contents of soils and it reduced 25 per cent of inorganic fertilizer application.

Application of FYM and vermicompost increased the soil microbial population. The organic manure produced more microbial biomass than inorganic and increased the proportion of labile carbon and nitrogen by directly stimulating the activity of the microorganism (Maheswarappa *et al.,* 1999).

Application of FYM increased the soil microbial load leading to mobilization of bound nutrients and improved the physical properties of soil (Aitken *et al.,* 1998). The activity of dehydrogenase and urease increased due to application of FYM as reported by Sriramachandrasekharan *et al.* (1997) and Reddy and Chonkar (1991).

Udayasoorian (1998) observed a positive influence of FYM on rice plant height, number of tillers $hill^{-1}$ and dry matter production with increased yield attributes and yield. Shanmugam and Veeraptharan (2001), revealed that application of FYM @ 12.5 t ha^{-1} + Azospirillum @ 2 kg ha^{-1} increased the productive tiller m^{-2}, filled grains per panicle, panicle length, grain yield and straw yield of rice. The growth and yield of maize were increased significantly with the application of enriched FYM (Tolessa and Friesen, 2001).

The application of FYM @ 5 and 10 t ha^{-1} significantly increased the growth and yield attributes of sunflower and quality of sunflower (Jagdev Singh and Singh (2000). Sharma and Misra (1997) reported enhancement in yield, water use efficiency, uptake of nutrients and protein yield of soybean due to combined use of FYM and reduced level of fertilizer. The mulberry growth and yield parameters were superior when a balanced dose of FYM @ 20 t ha^{-1} and fertilizers were applied (Shanker *et al.,* 2000).

Kumar *et al.* (2000) stated that sunflower yield was increased by about 25 per cent in red soil under rainfed condition when FYM was applied @ 20 t ha^{-1} along with fly ash @ 60 t ha^{-1}. Application of FYM and composted coir pith recorded the highest seed and stalk yield of sesamum (Hanumanthappa and Shivaraj, 2003). The maximum cane yield of 108.4 t ha^{-1} and sugar yield of 9.47 t ha^{-1} for the first crop and 96.8 t ha^{-1} cane and 9.18 t ha^{-1} sugar yields for the second crop (ratoon) were recorded where FYM at 15 t ha^{-1} accompanied with chemical fertilizer were applied (Bokhtiar and Sakurai, 2005).

2.6.2. Impact of fly ash on soil and crops

Fly ash is a major solid industrial waste in India. Huge amount of this fly ash is evolved in industries and dumped in ash disposed areas which creates the land degradation problems and may cause potential environmental hazards in spreading diseases and leaching of unwanted chemicals into ecosystem. To solve this problem, some efforts have been made to utilize it as an amendment to improve soil and its fertility and crop production (Sahoo and Kar, 1998).

Co-utilization of 'slash' a mixture of fly ash, sewage sludge and lime in the ratio of 60:30:10 had beneficial soil ameliorating effect (Reynolds *et al.,* 1999). Incorporation of 'slash' in soil had positive effects on soil pH and Ca, Mg and P content and reduction in the translocation of Ni and Cd (Rethman and Truter, 2001) and enhanced growth and yield of corn, potatoes and beans in pot trials. Application of fly ash at the rate of 40 t ha^{-1} in conjunction with phosphate solubilizer, *Pseudomonas striata* improved the bean yield and phosphorous uptake by grain (Gaind and Gaur, 2002).

Lal *et al*. (1996) observed highest dry matter yield of soybean in the treatment receiving 16 per cent fly ash. Agrawal *et al*. (2004) also observed an enhancement in protein content due to fly ash application in soybean, wheat, gram, sorghum and maize. Kumar *et al.* (2000) observed significant increase in Fe content of plants of various crops at higher level of fly ash incorporation i.e., beyond 8 per cent.

Addition of weathered coal fly ash at 5 per cent resulted in higher seed germination rate and root length of lettuce (*Lactuca sativa*) (Lau and Wong, 2001). The amino acid content in soybean (*Glycine max*) was found to show an increase when grown in fly ash-amended soils in pot cultures (Goyal *et al.,* 2002).

Fly ash applied at the rate of 25 per cent showed that higher yield of brinjal, tomato and cabbage. Oil seed crops such as sunflower and groundnut also responded favorably to fly ash amendment. Medicinal plants such as cornmint and vetiver were successfully planted in fly ash used in conjunction with 20 per cent FYM and mycorrhizae (Adholeya *et al.,* 1997; Sharma *et al.,* 2001a; Sharma *et al.,* 2001b). Khan and Singh (2001) also reported that 25 per cent of fly ash application increased plant length, number of branches and flowers of cosmos plant, while higher application rates reduced them significantly.

Application of 40 per cent fly ash found to have nematicidal effect and reduced the root knot disease in tomato caused by *Meloidogyne* sp. (Khan *et al.,* 1997). Tomato cultivars grown on fly ash amended soils had higher tolerance to wilt fungus *Fusarium oxysporum* (Khan and Singh, 2001).

2.6.3. Impact of biomanure on soil and crops

The use of compost can improve the physical, chemical and microbiological characteristics of cultivated soil, reduces the water requirement for plant growth by increasing the availability of moisture and increase the crop production (Gaur and Singh, 1995).

Application of decomposed paper mill waste at the rate of 5 to 10 t ha^{-1} improved the biological activity (Udayasoorian *et al.,* 1999b). Mini (1998) reported the increased availability of nutrients by the application of paper mill solid waste biomanure. The paper board mill treated effluent irrigation along with biocompost increased the vegetable cowpea yield upto 28 per cent when compared with normal farmers practice. The nodule formation was also increased up to 77 per cent and the equality of pod concerned with nutrient was also better (Prasanthrajan, 2001).

Arul (2002) reported that application of biocompost with treated effluent had a favorable effect on growth and flower weight and number of flowers in marigold. The yield of marigold was higher in effluent irrigation than well water. The yield was increased more than 40 per cent in biocompost amended plots than farmer practice. The quality traits of flowers *viz.,* vase life, essential oil and xanthophyll content were also increased under effluent irrigation.

The pod yield of groundnut cultivated under biocompost, prepared by mixing bagasse pith, activated sludge and ETP sludge at 2:1:1 ratio was comparable with the yield obtained from the crop cultivated under FYM application. The treated TNPL effluent irrigation resulted in higher pod yield than well water irrigation in groundnut crop (Udayasoorian *et al.*, 2004).

Amanullah (1997) reported that the growth parameters and yield of cassava increased due to application of organic manures especially composted poultry manure either alone or in combination with FYM. According to Kostov *et al*. (1995), the production of fruits on the compost applied field started 10 to 12 days earlier and compost treatments showed a significantly higher yield. Compost application has an added advantage of being suppressive to numerous plant diseases (Shyng, 1994) and weed population (Son, 1995).

Subbiah and Kumaraswamy (2000) studied the effect of different manure schedules on the soil properties and reported that application of organic manures had positive and significant influence on the fertility status of soil. The organic carbon content was significantly higher in the treatments that received organic manures. The availability of zinc and iron was increased by the incorporation of organic manures with no effect on the availability of manganese and copper (Appavu *et al*., 2000).

In radish and onion application of bio- compost @ 6 t ha $^{-1}$, fly ash @ 5 t ha $^{-1}$ and 100 per cent NPK to improve the tuber characters of radish *viz*., tuber length and girth, and bulb characters of onion *viz*., bulb length and girth were increased under effluent irrigation than well water irrigation (Prathiba, 2005).

2.6.4. Impact of vermicompost on soil and crop

Vermicompost contains most of the nutrients in plant available forms such as nitrates, phosphates and exchangeable Ca and soluble K (Edwards, 1998). Vermicompost is rich in microbial population and diversity, particularly fungi, bacteria and actinomycetes (Edwards, 1998). Marinari *et al.* (2000) reported that vermicompost had pH 7.7, 2.0 per cent of N, 34.2 per cent of total carbon, 813.0 μg N g^{-1} of N-NO_3, 133.7 μg N g^{-1} of N-NH_4, and 47.0 μg P g^{-1} of available P. Jayabal and Kuppuswamy (2001) reported that the NPK content of vermicompost was 1.50, 0.80, and 1.10 per cent, respectively.

Bhawalkar (1993) used vermicompost for reclamation of wasteland. Use of vermicastings as biofertilizer can be one of the measure to overcome productivity crisis in agriculture and play a multifaceted role in the improvement in soil texture through its influence on soil pH, as agent of physical decomposition by promoting humus formation, by improving soil texture and its enrichment.

Significant reduction, in bulk density was observed in treatment that received vermicompost (5 t ha $^{-1}$) along with chemical fertilizers than chemical fertilizers alone in rice field soil (Vasanthy and Kumaraswamy, 1999). Similar reduction in bulk density and increase in soil porosity was reported by Hangarge *et al.* (2002) in chillies and spinach grown fields due to vermicompost application.

Application of vermicompost @ 5 t ha^{-1} significantly increased organic carbon in soil (Srikanth *et al.,* 2000). The highest soil organic carbon was recorded in the vermicompost and pressmud treated with sesbania as intercrop under sugarcane field soil (Singh *et al.,* 2003).

Sharpley and Syres (1997) found increased P availability to plants when vermicompost was applied. Humic colloids in vermicompost are believed for playing an important role in controlling the availability of mineral ions through chelation (Purakayastha and Bhatnagar, 1997). Application of vermicompost @ 5 (or) 10 t ha^{-1} in strawberries increased the dehydrogenase activity and microbial biomass – N, increased amounts of NH_4 – N, NO_3-N and orthophosphates of soil (Arancon *et al.,* 2006).

Jat (2006) reported that the application of vermicompost at 8t ha^{-1} to chickpea crop resulted in higher dry matter (19.78 g / plant), leaf area index (1.57), pods per plant (27.38), seed (2.35 t ha^{-1}) and straw yield (3.81 t ha^{-1}) of chick pea. Dry fodder yield (7.51 t ha^{-1}) of maize and total N (171.67 kg ha^{-1}) and P (28.61 kg ha^{-1}) uptake by the chickpea - Maize cropping system also increased significantly with the application of vermicompost to chickpea.

Highest yield in sweet potato was reported for the treatment in which vermicompost was applied as organic manure with recommended dose of fertilizers (Pushpa, 1996). The highest dry matter production in chillies was recorded in the treated plot vermicompost + NPK by Rajalakshmi (1996). Chandrasekhar Reddy (2005) revealed that the application of vermicompost @ 10 t ha^{-1} has increased plant height, number of leaves per plant, leaf area, bulb length, diameter, weight and yield of onion. Coirpith vermicompost amended soil recorded the highest yield of onion (38.05 g $plant^{-1}$) in mine spoil (Thanunathan *et al*., 1997).

Jayanthi (2007) reported that application of vermicompost from paper board solid waste and treated effluent irrigation had a favorable effect on the growth parameters *viz.*, plant height, number of branches, number of leaves, number of flowers and flower characters of celosia. The vermicompost from paper mill sludge increased gerbera flower production, plant height, chlorophyll content, length and diameter of inflorescences (Rodriguez *et al*., 2000).

The above foregoing literatures reveal that the treated paperboard mill effluent and solid wastes could be used for crop production without any adverse effect on yield and quality of produce. However, the literature pertaining to effluent irrigation and solid waste application for chillies and brinjal on yield and quality are meager. So the present study was proposed.

CHAPTER III

MATERIALS AND METHODS

The present investigation on the effect of treated paperboard mill effluent irrigation and solid waste on growth, yield, quality of vegetables and soil were evaluated by conducting field experiments with brinjal and chillies as test crops. The experiments were carried out at Indian Tobacco company, paperboards and speciality papers division (ITC-PSPD) Unit : Kovai, Thekkampatti village, Mettupalayam, Coimbatore District of Tamil Nadu during 2007 2008. The details on field experiments, collection of plant, soil and effluent samples were analyzed in the department of Environmental Science, Tamil Nadu agricultural university, Coimbatore and the analytical methods followed are presented in this chapter.

PART I

3.1. ANALYSIS OF EFFULENT, WELL WATER AND SOLID WASTES

3.1.1. Collection of effluent and well water samples

The effluent samples were collected from ITC (PSPD) Unit: Kovai, Thekkampatti village, Mettupalayam and analysed for their physical, chemical and biological properties. Samples for microbial examinations were collected in sterilized bottles. The sampling bottles were closed with a round glass stopper having an overlapping rim. The stopper was relaxed by an intervening strip of paper to prevent breakage of the bottle during sterilization. The stopper and neck of the flask / bottles were protected by covering them with aluminium foil and sterilized in an auto clave at 20 psi for 15 minutes. The bottles were opened only at the time of sampling.

The samples for the analysis of dissolved oxygen (DO) were added with one ml of manganese sulphate solution and one ml of alkaline potassium iodide solution as given under the procedure for the estimation of dissolved oxygen. Samples for the determination of Biochemical Oxygen Demand (BOD) were preserved by adding five ml of washed chloroform (Chloroform and distilled water layer were discarded) per litre of the sample (APHA, 1980). Well water samples were also obtained from the model farm. The same collection and sampling procedures as in effluent samples were followed for well water samples also.

3.1.2. Characterization of effluent and well water samples

The physical, chemical and biological characteristics of the effluent and well water samples were analyzed as per the methods detailed in standard methods for the examination of water and wastewater (APHA, 1980).

Table. 3.1. Standard methods followed for the analysis of paperboard mill effluent and well water

Sl. No.	Parameters	Unit	Method	Reference
I .	**Physical properties**			
1.	Colour	-	Using Spectrophotometer and expressed in Platinum cobalt colour units	Gupta (2002)
2.	Suspended Solids	mg L^{-1}	A known quantity of the effluent was filtered using whatman No.1 filter paper and the residue was dried at 105^0C to a constant weight	Gupta (2002)
3.	Dissolved solids	mg L^{-1}	The filtrate obtained from the suspended solids was evaporated and dried at 105^0C to a constant weight	Gupta (2002)
4.	Total Solids	mg L^{-1}	A known quantity of the effluent was evaporated and dried at 105^0C to a constant weight	Gupta (2002)
II.	**Chemical properties**			
5.	pH	-	Measured using digital pH meter	Jackson (1973)
6.	EC	dS m^{-1}	Measured using conductivity bridge (CM 180 Elico conductivity Bridge)	Jackson (1973)
7.	DO	mg L^{-1}	Azide modification iodimetric method	APHA (1980)
8.	BOD	mg L^{-1}	Incubation method	Gupta (2002)
9.	COD	mg L^{-1}	Refluxed for 2 hours and titrated against 0.5 N FAS using Ferroin indicator	Gupta (2002)
10.	Organic Carbon	Per cent	Chromic acid wet digestion method	Walkley and Black (1934)
11.	Ammonical	mg L^{-1}	Bremner method	Jackson (1973)

Sl. No.	Parameters	Unit	Method	Reference
	Nitrogen			
12.	Phosphorus	mg L^{-1}	Photoelectric colorimeter at 660 nm	Olsen *et al.* (1954)
13	Carbonates	mg L^{-1}	Titrating with 0.1 N H_2SO_4 using phenolphthalein indicator	Piper (1966)
14.	Bicarbonates	mg L^{-1}	Titrating with 0.1 N H_2SO_4 using methyl orange indicator	Piper (1966)
15.	Calcium	mg L^{-1}	Versenate titration method	Jackson (1967)
17.	Magnesium	mg L^{-1}	Versenate titration method	Jackson (1967)
19.	Sodium	mg L^{-1}	Flame photometer	Jackson (1967)
20.	Potassium	mg L^{-1}	Flame photometer	Jackson (1967)
21.	Chloride	mg L^{-1}	Mohr's method	Jackson (1967)
22.	Sulphates	mg L^{-1}	Turbidimetric Method	Jackson (1967)
III.	**Biological properties**			
23	Bacteria	x 10^6 CFU g^{-1}	Nutrient agar	Waksman and Fred (1922)
24	Fungi	x 10^4 CFU g^{-1}	Martin's rose bengal agar	Waksman and Fred (1922)
25	Actinomycetes	x 10^3 CFU g^{-1}	Ken Knight's agar	Waksman and Fred (1922)

3.1.3. Analysis of solid wastes

3.1.3.1. Sample preparation

The samples collected from ITC (PSPD) were shade dried, sieved through 2mm nylon mesh sieve and stored in polythene bags. The samples thus prepared were taken for physical, chemical and biological analysis.

Table. 3. 2. Physico-chemical and biological analysis of solid wastes

Sl. No.	Particulars	Unit	Remarks	Reference
1.	pH	-	Sample: water suspension of 1:2.5	Jackson (1973)
2.	EC	dS m^{-1}	Sample: water suspension of 1:2.5	Jackson (1973)
3.	Organic carbon	Per cent	Wet digestion	Piper (1966)
4.	Total N	Per cent	Di acid extract	Jackson (1973)
5.	Total P	Per cent	Tri acid extract	Jackson (1973)
6.	Total K	Per cent	Tri acid extract	Jackson (1973)
7.	Total Ca and Mg	Per cent	Versenate titration method	Jackson (1973)
8.	Total Na	Per cent	Tri acid extract (EEL flame photometer)	Jackson (1973)
9.	Bacteria	x 10^6 CFU g^{-1}	Nutrient agar	Waksman and Fred (1922)
10.	Fungi	x 10^4 CFU g^{-1}	Martin's rose bengal agar	Waksman and Fred (1922)
11.	Actinomycetes	x 10^3 CFU g^{-1}	Ken Knight's agar	Waksman and Fred (1922)

PART II

3.2. FIELD TRIAL

Field trial were conducted in ITC (PSPD) model farm, Thekkampatti, Mettupalayam, Coimbatore District, Tamil Nadu to assess the impact of ITC treated effluent and solid wastes on crop growth, yield and quality of vegetables and soil.

Table. 3. 3. Details of field experiments

Particulars	Experiment I	Experiment II
Crop	Chillies	Brinjal
Variety	CO 4	PLR 1
Design	FRBD	FRBD
No.of treatments	8	8
No.of replication	3	3
Date of sowing	22.07.07	22.07.07
Date of transplanting	13.09.07	13.09.07
Plot size	3 x 4 m	3 x 4 m
Recommended NPK	30: 60: 30 kg ha^{-1}	50: 50: 30 kg ha^{-1}
FYM	25 t ha^{-1}	25 t ha^{-1}
Seed rate	1 kg ha^{-1}	400 g ha^{-1}
Spacing	45 x 30 cm	60 x 60 cm
Irrigation	Weekly intervals	Weekly intervals
After cultivation	Top dressing of N 30 kg ha^{-1} on 30, 60 and 90 days of planting	One hand weeding, top dressing of N 50 kg ha^{-1} and earthing up on 30 days after planting
No.of pickings	Five	Five

3.2.1. Treatment details

Factor 1: Irrigation sources

– **I_1** Well water

– **I_2** Treated paperboard effluent water

Factor 2: Amendments

T_1 : 100 % NPK (Control)

T_2 : FYM @ 12.5 t ha^{-1}+ 100 % NPK

T_3 : Fly ash @ 5 t ha^{-1} + 100 % NPK

T_4 : TNAU Biomanure @ 5 t ha^{-1}+ 100 % NPK

T_5 : Vermicompost @ 3.5 t ha^{-1}+ 100 % NPK

T_6 : TNAU Biomanure 5 t ha^{-1}+ Fly ash @ 5 t ha^{-1} + 100 % NPK

T_7 : Vermicompost @ 3.5 t ha^{-1}+ Fly ash @ 5 t ha^{-1}+ 100 % NPK

T_8 : TNAU Biomanure @ 5 t ha^{-1}+ Vermicompost @ 3.5 t ha^{-1} + Fly ash @ 5 t ha^{-1} +100 % NPK

3.3. ANALYSIS OF SOIL SAMPLES

3.3.1. Collection of soil samples

Soil samples were collected at 30, 60, 90 Days After Transplanting (DAT) and at harvest stage for brinjal and chilles from each plot. Shade dried and sieved through 2 mm sieve and stored in polythene bags for further analysis.

Table. 3. 4. Physico-chemical and biological analysis of soil samples

Sl. No.	Particulars	Unit	Remarks	Reference
I.	**Physical properties**			
1.	Bulk density	Mg m^{-3}	Wet cylinder method	Chopra and Kanwar (1982)
2.	Particle density	Mg m^{-3}	Wet cylinder method	Chopra and Kanwar (1982)
3.	Pore space	Per cent	Wet cylinder method	Chopra and Kanwar (1982)
II.	**Chemical properties**			
1.	pH	-	Soil: water suspension @ 1:2.5	Jackson (1973)
2.	EC	dS m^{-1}	Soil: water suspension @ 1:2.5	Jackson (1973)
3.	Organic carbon	Per cent	Wet digestion method	Walkley and Black (1934)
4.	Available N	kg ha^{-1}	Alkaline permanganate method	Subbiah and Asija (1956)
5.	Available P	kg ha^{-1}	Photoelectric colorimeter at 660 nm	Olsen *et al*. (1954)
6.	Available K	kg ha^{-1}	Flame photometer	Stanford and English (1948)
7.	Exchangeable Na	cmol (p^+) kg $^{-1}$	Ammonium acetate (Flame photometer)	Jackson (1973)
8.	Exchangeable Ca	cmol (p^+) kg $^{-1}$	Versenate titration method	Jackson (1973)
9.	Exchangeable Mg	cmol (p^+) kg $^{-1}$	Versenate titration method	Jackson (1973)
10.	Exchangeable K	cmol (p^+) kg $^{-1}$	Ammonium acetate extract (Flame photometer)	Jackson (1973)
15.	Exchangeable Sodium percentage	Per cent	$\frac{Na^+}{Na^+ + Ca^{++} + Mg^{++} + k^+} \times 100$	Saxena *et al.* (1978)

Sl. No.	Particulars	Unit	Remarks	Reference
III.	**Biological properties**			
11.	Bacteria	x 10^6 CFU g^{-1}	Nutrient agar	Waksman and Fred (1922)
12.	Fungi	x 10^4 CFU g^{-1}	Martin's rose bengal agar	Waksman and Fred (1922)
13.	Actinomycetes	x 10^3 CFU g^{-1}	Ken Knight's agar	Waksman and Fred (1922)

3.3.2. Soil enzymes activities

3.3.2.1. Urease

--- The urease activity in post harvest soil was measured according to the method prescribed by Hoffman (1965) and expressed as g of ammonical N released kg^{1} 24 h^{1}.

3.3.2.2. Phosphatase

The phosphatase activity of the soil was measured according to the method prescribed by Tabatabai and Bremner (1969) and expressed as µg PNP (Para nitro phenol phosphate) g^{-1} soil for 24 h^{1}.

3.3.2.3. Dehydrogenase

The dehydrogenase activity of the soil was measured according to the method prescribed by Chendrayan (1980) and expressed as µg of triphenyl formazan g^{-1} soil for 24 h^{1}.

3.4. PLANT BIOMETRIC OBSERVATION OF CHILLIES AND BRINJAL

3.4.1. Plant height

The height of the plant from the ground level to the tip of the main stem was measured at 30, 60, 90 DAT and expressed in centimeter.

3.4.2. Number of branches per plant

The numbers of branches per plant arising from main stem were counted at 30, 60, 90 DAT and expressed in number.

3.4.3. Fruit characters

3.4.3.1. Individual fruit weight

Ten fresh ripe fruits were selected randomly from the first two harvests and weighed. The mean fruit weight was computed and expressed in gram.

3.4.3.2. Fruit length

Five fruits from the first two harvests were selected randomly and the length of the individual fruit was measured immediately after harvest from the calyx end to the tip of the fruit and the mean was expressed in centimeter.

3.4.3.3 Fruit girth

The girth of three fruits was measured at the broadest point and the mean was expressed in centimeter.

3.5. FRUIT QUALITY TRAITS

3.5.1. Chillies fruit quality traits

3.5.1.1. Capsaicin content

The capsaicin content of dried fruit was estimated adopting the procedure given by Sadasivam and Manickam (1992). The dried fruit samples were finely ground and sieved through No. 40 sieve. Two grammes of the powder were taken in 100 ml volumetric flask. The volume was made upto 100 ml with 0.01 per cent ethyl acetate and kept as such for 24 hours. Then one ml of extract was taken and diluted to five ml with ethyl acetate. 0.5 ml of vanadium oxy choloride solution was added and shaken well. The samples were read at 720 nm in spectrophotometer. The standard curve was drawn using 0.5, 1.0, 1.5, 2.0 and 2.5 ml of standard solution containing 50,100,150, 200 and 250 µg capsaicin, respectively. The capsaicin content was estimated using the following formula and expressed in per cent.

$$\text{Capsaicin} = \frac{\mu\text{g capsaicin}}{1000 \times 1000} \times \frac{100}{1} \times \frac{100}{2}$$

3.5.1.2. Ascorbic acid

This procedure was suggested by Sadasivam and Manickam (1992). Five ml of working standard solution (10 ml of stock solution was diluted to 100 ml with 4 per cent oxalic acid. The concentration of working standard is 100 g /ml) was pipetted into a 100 ml conical flask. A quantity of 10 ml of 4 per cent oxalic acid was added and titrated against the dye (42 g of sodium bicarbonate was weighed into small volume of distilled water. 52 mg of 2,6- dichlorophenol indophenol was dissolved and the volume was made up to 200 ml with distilled water). End point was the appearance of pink colour, which persisted for few minutes. The amount of dye consumed was equivalent to the amount of ascorbic acid.

The sample was extracted (0.5 – 5 g depending upon the sample) in 4 per cent oxalic acid and made upto a known volume (100 ml) and centrifuged. A quantity of five ml of this supertnatant was pipetted out and titrated against the dye.

Amount of ascorbic acid was calculated as follows,

$$\text{Ascorbic acid (mg / 100 g sample)} = \frac{0.5 \text{ mg}}{V_1 \text{ ml}} \times \frac{V_2 \text{ ml}}{5 \text{ ml}} \times \frac{100 \text{ ml}}{\text{Wt of sample}} \times 100$$

where,

V_1 - Titrate value

V_2 - Amount of ascorbic acid present in the sample and expressed in grams.

3.5.1.3.Oleoresin

Oleoresin content was analysed as per the producedure of Malathi (1988). Oven dried fruits were powdered and a sample of five grams was taken in a glass column of soxhlet apparatus and oleoresin was estimated using acetone as organic solvent. The extract was then evaporated on the stream bath and heated for 30 minutes in an oven at 60 ^{o}C, cooled, weighed and the content was expressed in per cent.

3.5.2. Brinjal fruit quality traits

3.5.2.1. Ascorbic acid

The ascorbic acid content of fruit pulp was estimated by titrimetric method using 2, 6-di chlorophenol indophenol dye (Aberg, 1958) and expressed as milligrams per hundred grams of fresh weight.

3.5.2.2. Total phenols

Total phenols estimated as per the method of Bray and Thorpe (1954). Five grams of finely chopped tissue was boiled with 30 ml of 80 per cent ethanol in a water bath for 20 minutes. The supernatant was transferred to a 50 ml beaker and the tissue was again extracted with another 20 ml of 80 per cent ethanol for 20 minutes. The supernatant were combined and the final volume was brought to 25 ml by keeping on a water bath.

To one ml of this ethanol extract one ml of folin and cicalteu’s reagent and 2 ml of 20 per cent sodium carbonate were added, kept in a water bath exactly for 1 minute and then the volume was made upto 25 ml. The blue colour developed was read in a spectrophotometer at 624 nm. The phenolic concentration was arrived at by referring to a standard curve drawn by using catechol and expressed in terms of catechol equivalent as percentage.

3.6. STATISTICAL ANALYSIS

The data generated during this investigation for various characters were statistically analysed by the method given by Gomez and Gomez (1984). Results are presented and discussed at five per cent probability level uniformly. Treatment differences that are not significant were noted as non significant (NS).

CHAPTER IV

RESULTS

The present work was carried out to evaluate the effect of treated paperboard mill effluent as a source of irrigation in combination with solid wastes *viz.*, biomanure (BM), farm yard manure (FYM), fly ash (FA) and vermicompost (VC) on soil properties and quality of crop produce. Field experiments were conducted with chillies and brinjal as test crops during 2007 – 2008 at ITC (PSPD) Ltd., Thekkampatti, Mettupalayam, Coimbatore and the results are presented in this chapter.

4.1. INITIAL CHARACTERISTICS OF EXPERIMENTAL SOIL

The soil characteristics of both the experimental sites are presented in table 4.1. The initial soil pH of chillies field was 7.21 with an EC of 0.29 dS m^{-1}. The organic carbon content was 0.42 per cent. The available N, P and K were 131, 19.75 and 212 kg ha^{-1}, respectively. The exchangeable calcium, magnesium, sodium and potassium content were 6.95, 3.48, 1.62 and 0.08 cmol (p^{+}) kg^{-1}, respectively. The CEC of the soil was 12.13 (cmol (p^{+}) kg^{-1}) and ESP of 13.35, respectively. The total bacteria, fungi and actinomycetes population were 16.0 x 10^{6}, 5.0 x 10^{4}, 3.3 x 10^{3} CFU g^{-1} of soil, respectively. The initial soil pH of brinjal field was 7.34 with an EC of 0.31 dS m^{-1}. The organic carbon content was 0.47 per cent. The available N, P and K were 142, 20.14 and 216 kg ha^{-1}, respectively. The exchangeable calcium, magnesium, sodium and potassium content were 7.12, 3.57, 1.76 and 0.14 cmol (p^{+}) kg $^{-1}$, respectively. The CEC of the soil was 12.59 cmol (p^{+}) kg $^{-1}$ with ESP of 13.97, respectively. The total bacteria, fungi and actionmycetes population were 18.3 x 10^{6}, 5.0 x 10^{4}, 4.3 x 10^{3}, CFU g^{-1} of soil, respectively.

4.2. CHARACTERISTICS OF SOLID WASTE

The properties of various solid wastes used for the filed trials are listed in table 4.2. Among the solid wastes, fly ash (FA) was slightly alkaline in pH (8.21) with an EC of 0.98 dS m^{-1}. The Biomanure (BM), Farmyard manure (FYM) and Vermicompost (VC) showed a neutral pH with an EC of 1.26, 0.83 and 1.31 dS m^{-1}, respectively. The organic carbon content of BM, FYM and VC was 24.7, 22.5 and 25.1 per cent, respectively.

The nutrient content was the highest in vermicompost with the values of 1.78, 0.69 and 1.42 per cent of N, P and K, respectively. The bacteria, fungi and actinomycetes population were higher in vermicompost than biomanure and FYM. The microbial population was completely absent in FA.

4.3. CHARACTERISTICS OF TREATED EFFLUENT

The colour of the treated effluent let out for irrigation from ITC (PSPD) factory was colourless. During the period of study, the effluent recorded a pH of 7.10 with EC of 1.42 dS m^{-1} (Table 4.3.). The total dissolved and suspended solids of the effluent were 980 and 92 mg L^{-1}, respectively. The dissolved oxygen content was 4.8 mg L^{-1}. The BOD and COD of the effluent were 22.47 and 138.3 mg L^{-1}, respectively. The organic carbon content was 0.62 per cent. The calcium, magnesium and sodium content of the effluent were 290, 92 and 122.0 mg L^{-1}, respectively. The chloride and sulphate content of the effluent were 424 and 317 mg L^{-1}, respectively. The ammoniacal nitrogen, phosphorus and potassium content of the effluent were 24.7, 2.8 and 18.29 mg L^{-1}, respectively. The microbial population *viz.*, bacteria, fungi and actinomycetes were 24 x 10^6 CFU ml^{-1}, 7 x 10^4 CFU ml^{-1} and 5 x 10^3 CFU ml^{-1}.

4.4. CHARACTERISTICS OF WELL WATER

The characteristics of well water used for irrigation are given in table 4.3. The well water had pH of 7.20, EC of 0.43 dS m^{-1} and TDS of 236 mg L^{-1}. The dissolved oxygen content of the water was 5.6 mg L^{-1} and it had a BOD and COD of 6.10 and 42.0 mg L^{-1}, respectively. The calcium and magnesium content of well water were 13.2 and 7.1 mg L^{-1}, respectively. The microbial population *viz.*, bacterial, fungi and actinomycetes were 7 x 10^6, 3 x 10^4 and 2 x 10^3 CFU ml^{-1}, respectively.

4.5. IMPACT OF TREATED PAPERBOARD MILL EFFLUENT IRRIGATION AND SOLID WASTE ON CHILLIES AND BRINJAL

4.5.1. Growth Parameters

4.5.1.1. Plant height

The details on plant height of chillies and brinjal recorded at different growth stages are furnished in table 4.4. The treated paperboard mill effluent irrigation recorded taller plants than well water irrigation at all the stages in both chillies and brinjal crops.

In chillies crop, at 45, 90 Days After Transplanting (DAT) and at harvest stage the mean plant height ranged from 25.7 to 36.0, 31.9 to 42.4 and 48.4 to 67.4 cm, respectively. In brinjal crop, at 45, 90 DAT and at harvest stage the mean height ranged from 30.5 to 35.6, 39.4 to 48.2 and 56.2 to 64.8 cm, respectively.

The treatment T_8 (BM + VC + FA + 100 % NPK) recorded maximum plant height of 67.4 cm in chillies and 64.8 cm in brinjal at the time of harvest. The treatment T_1 (100 % NPK) recorded the shorter plants invariably at all the stages in both the vegetable crops. The interaction between irrigation and treatment was non significant.

4.5.1.2. Number of branches

The details on number of branches per plant at different stages of both crops are furnished in table 4.5. The treated paperboard mill effluent irrigation recorded maximum number of branches than well water irrigation at all the stages of crop growth.

In chillies, the treatment mean number of branches ranged from 2.00 to 3.15 at 45 DAT, whereas at 90 DAT and at harvest stage the mean number of branches varied from 3.33 to 4.33 and 4.50 to 6.33, respectively. In brinjal, at 45, 90 DAT and at harvest stage the mean number of branches ranged from 2.67 to 4.33, 5.17 to 6.33 and 6.83 to 8.00, respectively.

The treatment T_8 (BM + VC + FA + 100 % NPK) recorded the maximum number of branches (6.33) in chillies and (8.00) in brinjal at the time of harvest. The least value was observed in T_1 (100 % NPK). The interaction between irrigation and treatment was non significant.

4.5.1.3. Fruit weight

The data on fruit weight of chillies and brinjal are tabulated in table 4.6. In chillies crop, the mean fruit weight ranged from 6.23 to 10.92 g and in brinjal values ranged from 45.45 to 75.32 g. The fruit weight of chillies and brinjal significantly increased with effluent irrigation than well water irrigation.

Among the treatments T_8 (BM + VC + FA + 100 % NPK) recorded the highest weight irrespective of both crops, followed by T_7 (VC + FA + 100 % NPK) and the least values recorded in control (T_1). Significant interaction between irrigation and treatment was observed. The treatment combination I_2T_8 recorded the highest weight followed by I_2T_7 both in chilllies and brinjal crop and the least value was observed in I_1T_1.

4.5.1.4. Length and girth of chillies fruit

The details on fruit length and girth are furnished in table 4.7. The mean fruit length and girth ranged from 8.7 to 11.0 and 4.3 to 5.3 cm, respectively. The fruit length and girth significantly increased due to effluent irrigation.

The treatment T_8 (BM + VC + FA + 100 % NPK) recorded the maximum value of fruit length and girth followed by T_7 and the lowest length and girth was observed in T_1 (100 % NPK). Significant interaction effect was noticed between irrigation and treatments. The treatment combination I_2T_8 recorded maximum fruit length and girth than well water irrigation. Invariably all the treatments performed better under effluent irrigation (I_2).

4.5.1.5. Length and girth of brinjal fruit

The data on fruit length and girth of brinjal are furnished in table 4.8. The brinjal fruit length and girth ranged from 6.6 to 9.6 and 10.2 to 15.0 cm, respectively. The effluent irrigation significantly increased the fruit length and girth than well water.

Among the treatments, T_8 (BM + VC + FA + 100 % NPK) recorded the maximum fruit length followed by T_7 and T_5 and the lowest length and girth were observed in T_1. Significant interaction effect was noticed between irrigation and treatment. Invariably T_8 performed better both under effluent (I_2) as well as well water (I_1) irrigation. The lowest values of fruit length and girth were observed in I_1T_1 (well water irrigation with 100 % NPK).

4.5.1.6. Yield

The mean chillies yield ranged from 10.63 to 13.45 t ha^{-1} and in brinjal the yield ranged from 22.50 to 27.19 t ha^{-1}, respectively. Treated effluent irrigation significantly increased the yield in both chillies and brinjal crops (Table 4.9).

Among the solid waste, biomanure, vermicompost and fly ash with 100 % NPK (T_8) performed to be the best, irrespective of irrigation sources. The treatment (T_8) was significantly superior over control (T_1). The yield increase over control was 20.90 per cent in chillies and 17.28 per cent in brinjal. Significant interaction between irrigation and treatment was observed. The treatment combination I_2T_8 recorded the highest fruit yield of chillies (14.27 t ha^{-1}) and brinjal (28.41 t ha^{-1}) followed by I_2T_7.

4.6. SOIL PROPERTIES

4.6.1. Chemical properties

4.6.1.1. Soil pH

In chillies crop, the soil pH values at 45 DAT ranged from 7.24 to 7.55 and the corresponding values for 90 DAT and at harvest stage were 7.32 to 7.62 and 7.43 to 7.77, respectively (Table. 4.10.). The pH increased progressively till at the end of crop harvest stage.

In case of brinjal, the soil pH ranged from 7.28 to 7.54, 7.47 to 7.67 and 7.57 to 7.83 at 45, 90 DAT and at harvest stage.

The treatment T_3 (FA + 100 % NPK) recorded the highest pH value and the lowest value was observed in control (T_1). In both the crops treated effluent irrigation significantly increased the soil pH over well water irrigation. The interaction was non significant at all the stages of crop growth.

4.6.1.2. Electrical Conductivity (EC)

In chillies, the soil EC values ranged from 0.35 to 0.52, 0.41 to 0.54 and 0.46 to 0.58 dS m^{-1} at 45, 90 DAT and at harvest stage, respectively (Table 4.11). Comparatively, increased EC values were recorded at harvest stage over at 45 and 90 DAT under effluent irrigation.

The increase in soil EC was significantly higher in treatments containing fly ash with combination of 100 % NPK (T_3) over biomanure, vermicompost and its combination with fly ash (T_4, T_5, T_6, T_7, T_8). In case of brinjal, the mean EC ranged from 0.38 to 0.52, 0.44 to 0.54 and 0.49 to 0.59 dS m^{-1} at 45, 90 DAT and at harvest stage, respectively. The interaction was non significant at all the stages of the crop growth. The treatment T_3 recorded the highest EC value and the lowest value was observed in T_1. In both the crops treated effluent irrigation (I_2) significantly increased the soil EC over well water irrigation (I_1).

4.6.1.3. Organic Carbon (OC)

In general, organic carbon content of soil increased due to continuous effluent irrigation over well water irrigation in both chillies and brinjal crops (Table 4.12).

In chillies, the OC content of soil varied from 0.38 to 0.48 per cent and 0.43 to 0.55 per cent at 45, 90 DAT, respectively and 0.45 to 0.61 per cent at harvest stage. In case of brinjal the OC content of soil varied from 0.37 to 0.55 per cent, 0.41 to 0.58 per cent at 45, 90 DAT, respectively and from 0.45 to 0.60 per cent at harvest stage.

Among the solid waste, OC content of T_8 (BM + VC + FA + 100 % NPK) recorded the highest values, the least value was recorded in T_1 (100 % NPK) in both the crops. The interaction effect was significant and the treatment combination I_2T_8 recorded the highest OC content, over the other combination of treatments.

4.6.1.4. Available Nitrogen

The data on soil available nitrogen at different stages of chillies and brinjal are presented in table 4.13.

In general, the soil available nitrogen content increased up to 90 DAT and decreased at harvest stage in both the crops. The highest mean value of soil available nitrogen was recorded in effluent irrigation (I_2) at all the stages of chillies and brinjal crop growth than in well water irrigation (I_1).

Among the treatments, in chillies the mean available nitrogen content ranged from 136 to 182 kg ha^{-1}, 143 to 187 kg ha^{-1} and 125 to 166 kg ha^{-1} at 45, 90 DAT and at harvest stage, respectively. In case of brinjal, the values ranged from 137 to 175 kg ha^{-1}, 145 to 190 kg ha^{-1} and 140 to 185 kg ha^{-1} at 45, 90 DAT and at harvest stage. Among the solid wastes, T_8 recorded the highest available nitrogen content followed by T_7 and T_5 and lowest value was observed in T_1.

In both the crops, the available nitrogen was higher in effluent irrigation than well water irrigation at all the stages of crop growth. The interaction between irrigation and treatment was non significant.

4.6.1.5. Available phosphorous

The data on soil available phosphorus at different stages of chillies and brinjal are presented in table 4.14. In chillies, the mean values ranged from 19.88 to 23.85 kg ha^{-1}, 20.93 to 25.39 kg ha^{-1} and 20.37 to 23.42 kg ha^{-1} at 45, 90 DAT and at harvest stage, respectively. As in the case of available nitrogen, there was a reduction in the available phosphorus content of soil with the advancement in crop growth.

Among the solid wastes, T_8 recorded the highest available phosphorus content followed by T_7 and T_5 and the lowest value was recorded in T_1 at 45 DAT and 90 DAT. Similar trend was observed at harvest stage also.

In case of brinjal, the values ranged from 20.69 to 27.07 kg ha^{-1}, 20.93 to 27.29 kg ha^{-1} and 19.53 to 25.42 kg ha^{-1} at 45, 90 DAT and at harvest stage. In both the crops, the available phosphorus was higher in effluent irrigation than well water irrigation at all the stages of crop growth. The interaction effect between irrigation and treatment was non significant.

4.6.1.6. Available potassium

The details on available potassium content of the soil are furnished in table 4.15. The mean available potassium content in chillies ranged from 222 to 272 kg ha^{-1}, 224 to 275 kg ha^{-1} and 209 to 260 kg ha^{-1} at 45, 90 DAT and at harvest stage, respectively.

Among the treatments, T_8 (272 kg ha^{-1}) recorded the highest available potassium content followed by T_7 (258 kg ha^{-1}) and the least value was recorded under T_1 (222 kg ha^{-1}) at 45 DAT and very similar trend was noticed at 90 DAT and at harvest stage in chillies.

In case of brinjal, the values on available potassium ranged from 220 to 268 kg ha^{-1}, 224 to 273 kg ha^{-1} and 209 to 252 kg ha^{-1} at 45, 90 DAT and at harvest stage. In general, the available potassium content decreased at the end of harvest stage.

Among the treatment, similar trends were noticed as in the case of chillies crop. As in the case of other two major nutrients the available potassium was also higher under effluent irrigation in both the crops. The interaction between treatment and irrigation was non significant. The treatment T_8 recorded the highest value invariably at all the stages in both the crops and least value was recorded in T_1.

4.6.1.7. Exchangeable calcium

The results on soil exchangeable calcium content were tabulated in table 4.16. In chillies at 45 and 90 DAT, the mean exchangeable calcium content ranged from 7.54 to 8.62 and 7.75 to 8.71 cmol (p^+) kg^{-1} and at harvest stage the values ranged from 7.88 to 8.92 cmol (p^+) kg^{-1}.

As in the case of major nutrients, the exchangeable calcium content was higher under effluent irrigation than well water irrigation.

Among treatments, T_8 recorded higher exchangeable calcium content of 8.92 cmol (p^+) kg^{-1} followed by T_7, T_5 and T_4, which were significantly superior over control (T_1). In case of brinjal, at 45, 90 DAT, the mean exchangeable calcium content ranged from 7.76 to 8.53 and 7.89 to 8.85 cmol (p^+) kg^{-1} and at harvest stage the values ranged from 8.26 to 9.03 cmol (p^+) kg^{-1}.

In general, application of solid waste increased the exchangeable calcium content of soil than that of farmers practice (100 % NPK). Among the solid wastes, T_8 recorded the highest value and the lowest value in T_1 at 45 and 90 DAT. Similar trends were observed at harvest stage also. Interaction between irrigation and treatment was non significant at both crops.

4.6.1.8. Exchangeable magnesium

In chillies at 45 DAT and 90 DAT, the exchangeable magnesium content ranged from 3.72 to 4.78 cmol (p^+) kg^{-1} and 3.78 to 4.85 cmol (p^+) kg^{-1} and at harvest stage it was 3.97 to 5.04 cmol (p^+) kg^{-1} (Table 4.17). In case of brinjal, the exchangeable magnesium ranged form 3.57 to 4.72 cmol (p^+) kg^{-1}, 3.81 to 5.07 cmol (p^+) kg^{-1} and 4.01 to 5.16 cmol (p^+) kg^{-1} at 45, 0 DAT and at harvest stage, respectively.

Continuous effluent irrigation significantly increased the soil exchangeable magnesium content over well water irrigation. Among the treatments, T_8 recorded the highest soil exchangeable magnesium content and the least was in T_1. The interaction effect was non significant in both chillies and brinjal.

4.6.1.9. Exchangeable sodium

The details on the exchangeable sodium content of the soil are furnished in table 4.18. In chillies exchangeable sodium content of soil varied from 1.27 to 1.63 cmol (p^+) kg^{-1}, 1.52 to 1.76 cmol (p^+) kg^{-1} and 1.56 to 1.87 cmol (p^+) kg^{-1} at 45, 90 DAT and at harvest stage, respectively. In case of brinjal, the exchangeable sodium content from 1.30 to 1.62 cmol (p^+) kg^{-1}, 1.46 to 1.74 cmol (p^+) kg^{-1} and 1.51 to 1.82 cmol (p^+) kg^{-1} at 45, 90 DAT and at harvest stage, respectively.

Among the solid wastes, T_8 recorded the lowest value and the highest value in T_1 at 45 and 90 DAT. Similar trends were observed at harvest stage also. The exchangeable sodium content was higher under effluent irrigation than well water irrigation. The interaction between treatment and irrigation was non significant.

4.6.1.10 Exchangeable potassium

The mean exchangeable potassium ranged from 0.11 to 0.22 cmol (p^+) kg^{-1} and 0.15 to 0.26 cmol (p^+) kg^{-1} in chillies crop at 45 DAT and 90 DAT and at harvest stage ranged from 0.18 to 0.29 cmol (p^+) kg^{-1} (Table 4.19). The corresponding values for brinjal crop varied from 0.15 to 0.31 cmol (p^+) kg^{-1}, 0.17 to 0.36 cmol (p^+) kg^{-1} and 0.19 to 0.44 cmol (p^+) kg^{-1} at 45, 90 DAT and at harvest stage.

The soil exchangeable potassium content was also higher under effluent irrigation than well water irrigation at all the stages in both the crops.

The interaction effect was non significant in chillies at 45 DAT and at harvest stages of crop growth. The treatment combination I_2T_8 recorded highest soil exchangeable potassium content over rest of the treatment combinations of brinjal crop at 90 DAT.

4.6.1.11. Cation Exchange Capacity (CEC)

The mean CEC ranged from 13.23 to 15.84, 13.99 to 16.62 cmol (p^+) kg^{-1} in chillies crop at 45, 90 DAT and 14.18 to 16.71 cmol (p^+) kg^{-1} at harvest stage. The corresponding values for brinjal crop varied from 13.61 to 16.21, 14.02 to 16.25 and 14.80 to 17.29 cmol (p^+) kg^{-1} at 45, 90 DAT and at harvest stage, respectively (Table 4.20).

Continuous effluent irrigation significantly increased the soil CEC over well water irrigation till at the end of harvest stage in both the crops. Among the treatments, T_8 recorded the highest soil CEC and the least was in T_1 irrespective of crops. The interaction between effluent and treatment was non significant.

4.6.1.12. Exchangeable Sodium Percent (ESP)

The results on soil ESP were tabulated in table 4.21. In chillies at 45 and 90 DAT, the mean ESP ranged from 9.40 to 10.36 and 10.40 to 11.00 and at harvest stage the values ranged from 10.86 to 11.25, respectively.

As in the case of CEC, the soil ESP was higher under effluent irrigation than well water irrigation. In brinjal, at 45, 90 DAT, the mean ESP ranged from 9.55 to 10.27 and 10.16 to 10.47 and at harvest stage the values ranged from 10.21 to 10.51, respectively.

Among the solid wastes, T_8 recorded the lowest value and the highest value in T_1 at 45 and 90 DAT. Similar trends were observed at harvest stage also. Interaction between irrigation and treatment was non significant at both crops.

4.7. MICROBIAL POPULATION

4.7.1. Bacteria

The details on the bacterial population of soil are furnished in table 4.22. In chillies the soil bacterial population varied from 19.3 to 48.3, 30.2 to 54.2 and 36.8 to 64.2 x 10^6 CFU g^{-1} of soil at 45, 90 DAT and at harvest stage, respectively. In brinjal, the soil bacterial population varied from 18.8 to 48.7, 29.0 to 54.7 and 33.8 to 61.0 x 10^6 CFU g^{-1} of soil at 45, 90 DAT and at harvest stage, respectively.

As was the case with other parameters, the bacterial population was also higher under effluent than well water irrigation at all stages in both the crops.

The treatments with biomanure and vermicompost (T_4 to T_8) invariably recorded higher bacterial population. Among the treatments, BM + VC + FA + 100 % NPK (T_8) performed better than other treatments. The interaction between irrigation and treatment was significant. The treatment combination I_2T_8 recorded the highest bacterial population over rest of the treatment combinations.

4.7.2. Fungi

The details regarding the fungal population as influenced by irrigation sources and solid wastes are furnished in table 4.23.

In chillies the mean fungal population ranged from 6.0 to 19.5, 8.8 to 22.0 x 10^4 CFU g^{-1} of soil and 9.8 to 23.3 x 10^4 CFU g^{-1} of soil at 45, 90 DAT and at harvest stage, respectively. In brinjal the mean fungal population ranged from 5.5 to 19.8, 6.5 to 21.5 x 10^4 CFU g^{-1} of soil and 7.5 to 23.5 x 10^4 CFU g^{-1} of soil at 45, 90 DAT and at harvest stage, respectively.

Effluent irrigation recorded higher fungal population over well water irrigation. Application of biomanure or vermicompost either alone or in combination with fly ash (T_4 to T_8) increased the soil fungal population over control (T_1) and the lowest value was recorded in T_1. The interaction between irrigation and treatment was significant.

Among the treatment combinations, I_2T_8 (BM + VC + FA + 100 % NPK under effluent) recorded the highest soil fungal population at harvest stages followed by treatment I_2T_7 and the lowest population was recorded by I_1T_1. The same trend was also observed at all the stages of both the crops.

4.7.3. Actinomycetes

The actinomycetes population of the soil increased with advancement crop growth under both well water (I_1) and effluent irrigation (I_2). The treatment mean soil actinomycetes population of chillies ranged from 3.7 to 9.2, 6.5 to 13.7 x 10^3 CFU g^{-1} of soil and 7.0 to 17.0 x 10^3 CFU g^{-1} of soil at 45, 90 DAT and at harvest stage, respectively (Table 4.24).

In brinjal crop, the mean actinomycetes population ranged from 4.2 to 12.2, 5.3 to 13.2 x 10^3 CFU g^{-1} of soil and 6.8 to 14.8 x 10^3 CFU g^{-1} of soil at 45, 90 DAT and at harvest stage, respectively. The higher mean actinomycetes population was observed under effluent irrigation (I_2) than well water irrigation (I_1). The same trend was observed at all the stage of both the crops. The interaction between treatment and irrigation was found to be non significant.

4.8. SOIL ENZYMES ACTIVITY

4.8.1. Urease activity

The data on soil urease activity are presented in table 4.25 and 4.26. In chillies the soil urease activity ranged from 9.4 to 14.5 g of ammoniacal-N released kg^{-1} soil 24 h^{-1} in well water irrigation and 9.9 to 16.4 g of ammoniacal-N released kg^{-1} soil 24 h^{-1} in effluent irrigation, at harvest stage. In brinjal, the soil urease activity ranged from 9.3 to 14.4 and 9.6 to 14.6 of g of ammoniacal-N released kg^{-1} 24 h^{-1} in well water and effluent irrigation, respectively at harvest stage. Effluent irrigation significantly enhanced the soil urease activity.

Among treatments, T_8 (BM + VC + FA + 100 % NPK) recorded higher urease activity and the lowest value was observed in T_1 in chillies and a similar trend was observed in brinjal. The interaction effect was significant between treatment and irrigation. All the treatments with effluent irrigation enhanced the urease activity as compared to well water irrigation. The treatment combination I_2T_8 recorded the highest mean urease activity compare to other treatment combinations and the lowest value was recorded in I_1T_1.

4.8.2. Phosphatase activity

The data on soil phosphatase activity are furnished in table 4.25 and 4.26. In chillies, the soil phosphatase activity ranged from 37.5 to 58.0 and 39.7 to 62.5 µg PNPP g^{-1} of soil in well water and effluent irrigation, respectively at harvest stage.

In brinjal, the soil phosphatase activity ranged from 44.0 to 55.9 and 44.8 to 66.5 µg PNPP g^{-1} of soil in well water and effluent irrigation, respectively at harvest stages. Soil phosphatase activity increased due to continuous effluent irrigation.

Among the treatments, T_8 recorded higher phosphatase activity followed by T_7 (VC + FA + 100 % NPK) and T_5 (VC + 100 % NPK). The lowest value was recorded in T_1 in both the crops. Significant interaction between irrigation and treatment was observed. Invariably all the treatments performed better under effluent irrigation than well water irrigation.

4.8.3. Dehydrogenase activity

In chillies, the soil dehydrogenase activity ranged from 14.2 to 28.0 and from 16.3 to 29.6 µg TPF g^{-1} of soil 24 h^{-1} in well water and effluent irrigation, respectively at harvest stage. The corresponding values for brinjal ranged from 17.1 to 23.1 and 21.1 to 29.5 µg of TPF g^{-1} of soil 24 h^{-1} in well water and effluent irrigation, respectively (Table 4.25 and 4.26). Soil dehydrogenase activity increased due to continuous effluent irrigation.

Among the treatments, T_8 (BM + VC + FA + 100 % NPK) recorded higher dehydrogenase activity followed by T_7 (VC + FA + 100 % NPK) and T_5 (VC + 100 % NPK). The lowest value was recorded in T_1 (control) in both the crops. The interaction between irrigation and treatments was significant. Invariably all treatments performed better under effluent irrigation than well water irrigation.

4.9. CROP QUALITY PARAMETERS

4.9.1. Chillies

4.9.1.1. Ascorbic acid

The details on ascorbic acid content of chillies and brinjal are given in table 4.27. In chillies, the ascorbic acid content ranged from 20.67 to 51.32 and from 23.69 65.21 mg 100 g^{-1} in well water and effluent irrigation, respectively. The ascorbic acid in fruits was higher under effluent irrigation than of well water irrigation. Significant interaction between irrigation and treatment was observed. The treatment combination I_2T_8 recorded the highest ascorbic acid content over rest of the treatment combinations.

4.9.1.2. Capsaicin

The details on capsaicin content of chilies are given in table 4.27. The mean capsaicin content ranged from 0.49 to 0.70 mg 100 g^{-1}. The effluent irrigation had improved the capsaicin content in chillies crop. Among the treatments, T_8 (BM + VC + FA + 100 % NPK) registered the highest capsaicin content than other treatments. The interaction effect was significant between irrigation and treatment.

4.9.1.3. Oleoresin

The data on oleoresin content of chillies are given in table 4.27. The oleoresin content in chillies fruit in well water irrigation ranged from 11.32 to 14.95 mg 100 g^{-1} and under effluent irrigation from 11.78 to 15.52 mg 100 g^{-1}. The effluent water irrigation showed a significant increase in the oleoresin content than well water irrigation. The treatment combination I_2T_8 recorded maximum value and minimum value was recorded in I_1T_1. Invariably all treatments performed better under effluent irrigation than well water irrigation.

4.9.2. Brinjal

4.9.2.1. Ascorbic acid

The data on ascorbic acid content of brinjal are given in table 4.28. In brinjal crop, the mean ascorbic acid content ranged from 11.43 to 12.68 mg $100g^{-1}$. Among the solid wastes, T_8 registered higher ascorbic acid which was on par with T_7, T_6, T_5 and T4. The lowest ascorbic acid content was recorded in treatment T_1. All the treatments with effluent irrigation enhanced the ascorbic acid content as compared to well water irrigation. Significant interaction between irrigation and treatment was observed.

4.9.2.2. Phenol

The details on phenol content of brinjal are given in table 4.28. The phenol content of fruit under well water irrigation ranged from 1016 to 1152 μg g^{-1} and under effluent irrigation it ranged from 1076 to 1225 μg g^{-1}. Among the treatments, the treatment combination I_2T_8 showed highest content of phenol compare to other treatments. Quantity of phenol content was more under effluent irrigation than well water irrigation. The interaction between treatment and irrigation was non significant.

CHAPTER V

DISCUSSION

During the past few decades, Indian industries have registered a quantum jump, which has contributed to high economic growth but simultaneously it has also given rise to severe environmental pollution. Huge quantity of solid wastes and effluents generated from different industries are being dumped into the environment, causing hazards in the long run. Application of effluent on land as irrigation water, source of plant nutrients offers a promising alternative. This effective management of wastes brings economic benefits and protects fragile ecosystem from degradation. An attempt was made to find out the impact of paperboard mill effluent irrigation and solid wastes on yield and quality of chillies and brinjal crops.

This is one of the alternatives that have to be considered as a way to transform these wastes as resource to plant and soil, at the source time diminishing their negative environment impact. The study clearly shows that the yield and quality of chillies and brinjal were improved due to effluent irrigation and amendment application. The details regarding the results of present investigation are discussed in this chapter with supporting literatures.

5.1. CHARACTERISTICS OF SOILS, SOLID WASTES, TREATED EFFLUENT AND WELL WATER

5.1.1. Initial characteristics of soil

The initial experimental soils had neutral pH with an EC of 0.29 dS m^{-1} in chillies and 0.31 dS m^{-1} in brinjal. The available nutrient content of soil revealed that the soil had low N and medium content of P and K in both the fields. The organic carbon content was low in the experimental soils. The CEC indicated that the exchange sites in the soils were with less cations. The soil had supported considerable amount of microbial population.

5.1.2. Initial characteristics of solid wastes

The pH was neutral in farmyard manure (FYM), vermicompost (VC) and biomanure (BM) whereas, the pH of the fly ash was alkaline. Elyarajan (2002) reported that the pH of fly ash from paperboard mill effluent was alkaline in nature and it provides essential plant nutrients to the soil. Similar results were reported by Prasanthrajan (2001) and Arul (2002). Among the solid wastes used, the organic carbon content was more or less same except fly ash.

5.1.3. Characteristics of the treated effluent

The pH of treated paperboard mill effluent was 7.10, since lime was used to neutralize the effluent before primary and secondary treatment process. The electrical conductivity of the effluent was 1.42 dS m^{-1}, this is because of the fact that paper mill manufacturing uses various inorganic chemicals *viz.*, caustic soda, talc, rosin etc. Similar results have been reported by Juwarker and Subrahmanyam (1987).

In general, the vital quality parameters *viz.*, pH, EC, TDS, BOD, COD, chloride and sulphate values of treated effluent were well within the permissible limits of TNSPCB (Tamil Nadu State Pollution Control Board) norms. The treated effluent had considerable amount of essential nutrients *viz*., ammoniacal nitrogen, phosphorus, potassium, calcium and magnesium. The paperboard mill effluent supported a considerable amount of microbial population. The present study is in the line with the findings of Elayarajan (2002).

5.1.4. Characteristics of well water

The pH and EC were well below the treated effluent values. Dissolved oxygen in the well water was higher than that of treated effluent. The BOD and COD values were less than these in the treated effluent. The microbial populations in the well water were much less than that of treated effluent. The parameters analyzed in well water for the present study were similar to the findings of Prasanthrajan (2001), Arul (2002) and Prathiba (2005).

5.2. IMPACT OF TREATED PAPERBOARD MILL EFFLUENT IRRIGATION AND SOLID WASTES ON CHILLIES AND BRINJAL

Application of paperboard mill solid waste and treated effluent had a favorable effect on vegetables *viz.*, chillies and brinjal.

5.2.1. Biometric characters

The biometric characters are the indicators of the influence of nutrients present in the effluent and other ameliorants. Significant influence of various ameliorants on the plant height and branches of crops at different growth stages was recorded in the present study.

Application of VC + BM + FA + 100 % NPK had a favorable influence on plant growth attributes in chillies and brinjal at all the stages of growth period with effluent irrigation compared to well water irrigation (Fig. 1). Because treated effluent supplies the appreciable amounts of plant nutrients than well water. Moreover, the response of plants to wastewater irrigation depends on many factors such as climate and nature of pollutant. This is in line with the observation recorded by Sandana (1995) who reported higher root length, shoot length and number of branches in tomato amended with bioearth under treated paper mill effluent irrigation.

In the present study, the inorganic nitrogen and other essential plant nutrients contributed from vermicompost, biomanure and fly ash might have helped in the promotion of the growth characters of both the crops. The same phenomenon of maximum plant height was observed in vermicompost amended treatment by Chandrasekhar Reddy (2005). Prasanthrajan *et al.* (2004) also reported maximum plant height and the highest number of branches were recorded in vegetable cowpea when grown on biocompost amended soil with paper mill effluent irrigation. This was mainly due to ameliorative effect of organic manures on soil.

5.2.2. Yield

The fruit yield of both the crops was more under VC + BM + FA + 100 % NPK (T_8) with effluent irrigation than well water irrigation. This could be due to increased level of major nutrients in the effluent which might have contributed to higher yield of the crops. Application of VC + BM + FA + 100 % NPK had favorable influence on yield attributing characters of chillies and brinjal *viz.,* fruit weight, fruit length and fruit girth with effluent irrigation. Similar results were also expressed by Neena Dhiman and Battish (2005) who had reported that application of vermicompost was increased the fruit yield in chillies, might be due to increased number of fruit, fruit weight, fruit length and fruit girth.

In general, growth attributes are directly correlated to the yield of vegetable crops. Among the solid wastes and organic manures, the vermicompost contained highest N content followed by biomanure. Addition of these organic manures enhances the growth attributes like number of leaves and number of branches and it leads to increased photosynthesis to crops. This will facilitate increased yield in crops. In the present study, the treatment receiving VC + BM + FA + 100 % NPK along with effluent irrigation highest fruit yield compared to other treatments (Fig. 2). The similar trend was observed by Prasanthrajan *et al.* (2004), the application of paperboard mill effluent irrigation along with biocompost increased the pod yield in vegetable cowpea. Malathi (2001) also observed increased yield of bhendi and amaranthus under effluent irrigation along with amendments. Among the solid wastes and organic manures, fly ash had no favorable influence on the crop yields owing to its inherently low nutrient concentration.

5.3. IMPACT OF PAPER BOARD MILL TREATED EFFLUENT AND SOLID WASTES ON SOIL PROPERTIES

Application of paperboard mill effluent and solid wastes had a favorable influence on soil properties.

5.3.1. Physico-Chemical properties of soil

The treatment receiving fly ash along with effluent irrigation had increased soil pH in both chillies and brinjal at harvest stage (Fig. 3). Among the amendments, the combination with biomanure and vermicompost had decreased soil pH value, this might be due to the organic acids released through microbial decomposition of organic amendments as reported by Olaniya e*t al*. (1991). In the present study, the progressive increase in pH of soil was recorded in plots receiving effluent irrigation. Similar findings were also expressed by Vanconcelos and Cabral (1993), Elayarajan (2002) and Pathan *et al*. (2003).

The electrical conductivity of the soil in both the crops was higher under effluent irrigation as compared to well water irrigation, owing to the increased amount of soluble salts content in the effluent. The effluent also contained higher quantity of organic polyelectrolyte, which binds divalent cations resulting in higher EC under effluent irrigation (Udayasoorian *et al*., 2004). The higher EC value was recorded in treatment T_3 (FA + 100 % NPK) irrigated with effluent and least value was recorded in T_1 (control), owing to the non addition of salt bearing materials (Fig. 4). Similar observation in soil EC due to effluent irrigation had been noticed by Dhevagi *et al*. (2000), Elayarajan (2002) and Singh and Room Singh (2005).

The organic carbon content was higher when soil irrigated with effluent compared to well water. The increase in organic matter content of the effluent irrigated soil might be due to higher concentration of organic loads, which would contribute to build up of organic matter (Chatterjee *et al*., 2003). Among the amendments, vermicompost and biomanure recorded the highest OC, the increase in soil organic matter content was due to the addition of various organic amendments (Fig. 5). The organic amendments were rich in organic carbon and hence the soil treated with them had higher organic carbon content. The build up of the soil organic mater under effluent irrigation would sustain soil health and enhance soil productivity. The higher value was recorded in the treatment having VC + BM + FA. This was in line with findings of Dhevagi *et al*. (2003), reported that the paper mill effluent irrigation along with amendments increased organic matter content from 0.51 to 0.67 per cent.

Application of VC + BM + FA + 100 % NPK along with effluent irrigation recorded the highest soil available nitrogen than well water irrigation (Fig. 6). This is in line with the findings of Ramasubramaniam *et al.* (2001) and Udayasoorian *et al.* (2003) whose report explained that the addition of organic matter in the form of amendments have provided the source of N for the multiplication of microbes and subsequent increase in the nutrient availability of soil. However, with the advancement of crop growth, there was a decline in available N content. Because nitrogen loss occurs through volatilization and leaching process, apart from crop uptake. Similar result in bhendi and amaranthus under paper mill effluent irrigation was observed by Malathi (2001).

The available phosphorus content was higher under effluent irrigation as compared to well water. This could be due to relatively higher phosphorus content of the effluent. In present investigation, VC + BM + FA +100 % NPK recorded the higher available P content (Fig. 7). This might be due to vermicompost, biomanure and ash can serve as a slowly soluble phosphorus fertilizer (Issakainen *et al*., 1994). The available phosphorous content of soil was decreased with the advancement of crop growth due to crop removal. This was in accordance with the findings of Pushpavalli (1990), Oblisami and Palanisami (1991) and Sandana (1995).

The soil available K content was also higher under effluent irrigation. Srinivasachari *et al*. (1999) also supported these findings, who reported that enhanced potassium content of soil due to effluent irrigation. Among the treatments, T_8 (VC + BM + FA + 100 % NPK) recorded higher soil available K content and the least was recorded in control (T_1) (Fig. 8). Addition of VC + BM + FA contributes significant amount of K to soil than other treatments. Due to continuous crop uptake there was an uniform reduction in available K content with the advancement of crop growth. Similar results were also observed by Malathi (2001).

There was an increase in exchangeable calcium, magnesium, sodium and potassium contents of the soil under effluent irrigation than in well water (Fig. 9). Higher concentration of exchangeable cations under effluent irrigation was reported by number of workers (Gomathi and Oblisami, 1992; Hameed and Udayasoorian, 1999). The continuous application of effluent may result in enrichment of macro and micro nutrients in to top soil (Srinivaschari *et al*., 1998a). The exchangeable calcium and magnesium were higher in treatments receiving VC + BM + FA + 100 % NPK in both the crops. Presence of higher concentrations of Ca and Mg in vermicompost, biomanure and fly ash might have increased the concentrations of these cations in soil. Since the crop removal of these elements might be lower compared to the amount added, there was a build up in the soil with the advancement of crop growth. This is in accordance with the findings of Prasanthrajan (2001) in biocompost and Suthar (2006) in vermicompost.

The CEC was significantly increased under effluent irrigation when compared to well water irrigation. Increase in CEC might be due to higher concentration of cations present in effluent. Among the treatments, VC + BM + FA + 100 % NPK recorded the highest CEC than rest of treatments (Fig. 10). Selvakumari *et al*. (1999) has also observed an increase in soil CEC, exchangeable Ca, Mg and available micronutrients as a result of mixing fly ash with organic amendments to soil. Similar view points were also expressed by Singh and Yunus (2000), who reported that fly ash application increased the concentration of B, Mo, Ca, Cr, K, Mg, Na and P.

5.3.2. Microbial population

The bacterial, fungal and actinomycetes populations were comparatively higher in effluent irrigation along with amendments than in well water irrigation, which might be due to prevalence of adequate amount of nutrients in effluent and amendments. In the present study, vermicompost and biomanure applied soils increased the biological activity, which could be ascribed to the fact that organic matter serves as a storehouse of food for microbes. Humic substances in compost would have also contributed to the increase in the level of soil microflora (Appavu *et al*., 2000). Addition of organic matter in the form of compost and organic matter content of effluent might have enhanced the survival of the soil microorganisms.

The treatment T_8 (VC + BM + FA + 100 % NPK) recorded the highest bacteria, fungi and actinomycetes population at all stages of both the crops. Similar trends were also observed when soil amended with biocompost (Prasanthrajan, 2001) and vermicompost (Mba, 1994). Paper mill effluent along with amendments had increased the soil microbial population (Dhevagi *et al*., 2003 and Udayasoorian *et al*., 2003).

5.3.3. Soil enzymes

In the present investigation there was an increase in urease, cellulase and phosphatase activity in soils with an increase in the period of effluent irrigation (Fig. 11, 12 and 13). This increase might be due to increased microbial populations, which help in the mineralization and degradation of organic matter. The increase in organic matter content, which serves as a nutrient source for microorganisms, might increase the enzyme activity under effluent irrigated soils. This is parallel to the results of Dhevagi *et al*. (2003), who reported that the paper mill effluent irrigation along with amendments increased the soil enzyme activity.

Among the amendments, the combination of vermicompost, biomanure and fly ash with 100 % NPK recorded the highest soil enzyme activities. It implies that organic and inorganic nutrients might have provided a nutrient rich environment, which is essential for the production of enzymes. Besides, addition of organic manures to soil enhances the soil organic carbon status and microbial activity or diversity, which subsequently enhance soil enzymes synthesis and accumulation.

5.3.4. Quality parameters

With reference to quality parameters of chillies *viz.*, ascorbic acid, capsaicin, oleoresin contents were higher in paperboard mill effluent irrigation when compared to well water irrigation (Fig. 14 and 15). Ascorbic acid and phenol contents of brinjal were also higher in effluent irrigation (Fig. 16). In both the crops, the quality parameters were better in treatment receiving VC + BM + FA+ 100 % NPK. This might be due to combined use of treated effluent along with amendments, which might have provided enough nutrients with better physical and microbial environment and thus improving the soil fertility and ultimately resulted in improved quality parameters. Similar results were also reported in tomato (Sandana, 1995), radish and onion (Prathiba, 2005), bhendi (Rathinasamy and Narashimhan, 1998; Malathi, 2001), when grown in organic amended soil with paper mill effluent irrigation.

Udayasoorian *et al.* (1999a) also observed improvement in tomato fruit quality parameters such as total solid content, ascorbic acid and NPK content, when the plants were grown in bioearth amended soils along with paper mill effluent irrigation. The quality parameters of banana *viz.*, total and non-reducing sugars, ash, K, Na Mn and Cu were also found increased under paperboard mill effluent irrigation (Prabakaran, 2003).

CHAPTER VI

SUMMARY AND CONCLUSION

Generation of solid and liquid wastes increased due to rapid growth of industrialization and globalization. As an alternate way, utilization of these wastes for crop growth provides the best solution to minimize pollution and also helps to recycle the nutrients back into the soil. An attempt has been made to use the treated effluent and solid wastes from ITC (PSPD) Unit: Kovai for cultivating vegetable crops *viz.*, chillies and brinjal and also to study their impact on soil and crop quality. The salient findings and conclusion that emerged out of the present study are summarized as below.

Characteristics of treated effluent

- ✳ The treated effluent from ITC (PSPD) paperboard mill was colourless with neutral pH having an EC of 1.42 dS m^{-1}. The effluent had moderate quality of organic carbon and dissolved oxygen content. The BOD, COD, total and dissolved solids are well within the standards of state pollution control board. The treated paperboard mill effluent had appreciable amount of calcium, magnesium, ammonical nitrogen, phosphorous, potassium and sulphate.
- ✳ The number status of treated paperboard mill effluent was comparatively higher than well water. The treated paperboard mill effluent supported considerable bad of microbial population.

Yield and yield attributes of chillies and brinjal

- ✳ Application of biomanure, vermicompost and fly ash along with 100 % NPK under treated paperboard mill effluent irrigation had a favorable effect on the growth of chillies and brinjal.
- ✳ The yield attributes *viz*., length and girth of fruit and fruit weight of chillies and brinjal were significantly increased in BM + VC + FA + 100 % NPK under treated paperboard mill effluent irrigation.
- ✳ The yield increase was 20.90 per cent in chillies and 17.28 per cent in brinjal under BM + VC + FA + 100 % NPK than that of control (100 % NPK).

Impact on soil quality

- Continuous effluent irrigation increased the soil pH and EC at all stages of crop growth, irrespective of solid waste addition.
- Organic carbon content of soil increased irrespective of solid waste addition. Among the treatments, BM + VC + 100 % NPK and VC + FA + 100 % NPK had recorded higher organic carbon content under treated paperboard mill effluent irrigation.
- The available N, P and K content of experimental soil were higher in effluent irrigation than in well water irrigation. A decrease in available nutrients content was observed at later stage crop growth in both the experimental soils. The soil receiving biomanure + vermicompost + fly ash + 100 % NPK were recorded higher soil available N, P and K.
- The soil irrigated with effluent registered a considerable increase in exchangeable cations than in well water irrigation. Biomanure + vermicompost + fly ash + 100 % NPK amended soil recorded the highest exchangeable cations than the rest of treatments.
- The soil irrigated with treated paper board mill effluent irrigation recorded higher microbial population than well water irrigation. It clearly emphasis that the effluent irrigated soil supports the growth of microbes viz., bacteria, fungi and actinomycetes.
- The enzyme activities on overall perspective increased with effluent irrigation than well water irrigation. The urease, phosphatase, dehydrogenase activities increased considerably indicating that the soil is healthy and good enough to support crops.

Quality of chillies and brinjal

The quality of chillies and brinjal fruits were not affected due to effluent irrigation and solid waste addition. The ascorbic acid, capsaicin and oleoresin in chillies fruits, ascorbic acid and phenol in brinjal fruits were not affected by treated effluent irrigation. Infact there parameters were slightly improved. Based on the results, it could be concluded that the treated paperboard mill effluent can be used as effective irrigation source with addition of solid wastes viz., biomanure, vermicompost and fly ash as plant nutrients along with 100 % recommended NPK.

The effluent irrigation and solid waste had provided necessary plant nutrients to chillies and brinjal, resulting in higher yield and without causing any adverse effect on soil health and crop quality parameters.

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Table 4.4. Effect of treated paperboard mill effluent irrigation and solid waste on plant height (cm)

Treatments	**Chillies**									**Brinjal**								
	45 DAT			**90 DAT**			**At harvest**			**45 DAT**			**90 DAT**			**At harvest**		
	I_1	**I_2**	**Mean**	**I_1**	**I_2**	**Mean**	**I_1**	**I_2**	**Mean**	**I_1**	**I_2**	**Mean**	**I_1**	**I_2**	**Mean**	**I_1**	**I_2**	**Mean**
T_1	24.4	27.0	**25.7**	31.4	32.5	**31.9**	45.7	51.0	**48.4**	29.7	31.3	**30.5**	38.5	40.3	**39.4**	54.5	57.8	**56.2**
T_2	26.5	32.0	**29.3**	33.5	43.0	**38.3**	51.5	53.7	**52.6**	31.8	33.3	**32.6**	40.7	43.5	**42.1**	59.4	62.6	**61.0**
T_3	23.1	28.5	**25.8**	30.6	35.0	**32.8**	45.2	52.6	**48.9**	30.6	31.8	**31.2**	39.7	40.9	**40.3**	54.5	62.5	**58.5**
T_4	27.0	30.5	**28.8**	33.7	39.5	**36.6**	52.3	56.0	**54.2**	33.0	34.3	**33.7**	40.1	43.8	**42.0**	58.1	63.1	**60.6**
T_5	31.3	33.7	**32.5**	37.4	43.1	**40.3**	55.1	59.3	**57.2**	34.0	35.3	**34.7**	40.3	47.8	**44.1**	61.7	61.2	**60.7**
T_6	26.8	31.5	**29.2**	34.0	40.4	**37.2**	56.0	57.1	**56.6**	30.6	33.0	**31.8**	39.5	40.4	**40.0**	55.5	61.8	**58.7**
T_7	32.0	34.0	**33.0**	37.0	44.1	**40.6**	61.0	62.5	**61.8**	33.5	36.4	**35.0**	42.5	46.2	**44.4**	62.5	65.2	**63.9**
T_8	34.5	37.4	**36.0**	39.1	45.6	**42.4**	65.5	69.2	**67.4**	34.0	37.2	**35.6**	46.7	49.6	**48.2**	63.9	65.7	**64.8**
Mean	**28.2**	**31.8**		**34.6**	**41.0**		**54.0**	**57.7**		**32.2**	**34.1**		**41.0**	**44.1**		**58.6**	**62.6**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.63		1.28	0.79		1.61	1.17		2.40	0.29		0.60	0.37		0.77	0.54		1.10
T	1.26		2.57	1.58		3.23	2.35		4.80	0.59		1.20	0.75		1.54	1.08		2.20
IT	1.78		NS	2.24		NS	3.33		NS	0.83		NS	1.068		2.18	1.52		3.12

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.5. Effect of treated paperboard mill effluent irrigation and solid wastes on number of branches

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	2.00	2.00	**2.00**	3.33	3.33	**3.33**	4.33	4.67	**4.50**	2.67	2.67	**2.67**	5.67	4.67	**5.17**	7.00	6.67	**6.83**
T_2	3.00	3.00	**3.00**	3.67	4.00	**3.83**	5.33	6.00	**5.67**	3.00	3.00	**3.00**	5.33	5.67	**5.50**	7.00	7.67	**7.34**
T_3	2.00	2.00	**2.00**	3.33	3.33	**3.33**	5.33	5.00	**5.17**	3.33	3.33	**3.33**	5.00	5.33	**5.17**	6.67	7.67	**7.17**
T_4	3.00	3.00	**3.00**	3.67	4.00	**3.83**	5.67	5.67	**5.67**	2.67	3.00	**2.83**	5.67	5.67	**5.67**	7.00	7.33	**7.17**
T_5	3.00	3.00	**3.00**	4.00	4.00	**4.00**	5.33	6.00	**5.67**	2.67	3.67	**3.17**	5.67	6.00	**5.83**	7.67	7.67	**7.67**
T_6	2.00	2.00	**2.00**	3.67	3.67	**3.67**	5.33	5.33	**5.33**	3.33	2.67	**3.00**	4.67	6.00	**5.34**	7.67	7.67	**7.67**
T_7	3.00	3.30	**3.15**	4.00	4.00	**4.00**	6.00	6.33	**6.17**	3.67	3.33	**3.50**	6.00	6.00	**6.00**	7.67	8.00	**7.83**
T_8	3.00	3.30	**3.15**	4.33	4.33	**4.33**	6.33	6.33	**6.33**	4.33	4.33	**4.33**	6.33	6.33	**6.33**	7.67	8.33	**8.00**
Mean	**2.63**	**2.70**		3.75	3.83		**5.46**	**5.67**		**3.21**	**3.25**		**5.54**	**5.71**		**7.33**	**7.46**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.04		0.08	0.13		NS	0.19		0.40	0.15		NS	0.20		NS	0.16		NS
T	0.08		0.17	0.26		0.54	0.39		0.80	0.30		0.62	0.41		NS	0.33		0.67
IT	0.11		0.24	0.38		NS	0.55		1.13	0.43		NS	0.58		NS	0.46		NS

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.6. Effect of treated paperboard mill effluent irrigation and solid waste on fruit weight (g^{-1}) of chillies and brinjal at harvest stage

Treatments	Chillies			Brinjal		
	I_1	I_2	Mean	I_1	I_2	Mean
T_1	5.81	6.64	**6.23**	43.60	48.30	**45.45**
T_2	7.36	7.41	**7.39**	53.40	54.50	**53.95**
T_3	6.60	6.68	**6.64**	42.10	49.20	**45.65**
T_4	7.55	7.95	**7.75**	56.20	58.90	**57.55**
T_5	8.38	9.16	**8.77**	61.40	62.60	**62.00**
T_6	7.36	8.11	**7.74**	54.28	56.40	**55.34**
T_7	8.48	10.36	**9.42**	61.21	72.40	**66.81**
T_8	10.37	11.47	**10.92**	71.43	79.20	**75.32**
Mean	**7.74**	**8.47**		**55.45**	**60.06**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.11		0.22	0.77		1.57
T	0.21		0.43	1.54		3.14
IT	0.30		0.61	2.18		4.45

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.7. Effect of treated paperboard mill effluent irrigation and solid waste on fruit length and girth (cm) of chillies

Treatments	Length			Girth		
	I_1	**I_2**	**Mean**	**I_1**	**I_2**	**Mean**
T_1	8.2	9.1	**8.7**	4.4	4.2	**4.3**
T_2	8.7	9.8	**9.2**	4.3	5.1	**4.7**
T_3	8.3	9.3	**8.8**	4.8	3.9	**4.6**
T_4	9.9	10.2	**10.1**	4.2	5.1	**4.7**
T_5	9.5	10.7	**10.1**	4.6	5.6	**5.1**
T_6	10.2	9.6	**9.9**	4.1	5.4	**4.8**
T_7	9.8	10.4	**10.1**	4.8	5.7	**5.2**
T_8	10.7	11.3	**11.0**	4.8	5.8	**5.3**
Mean	**9.4**	**10.1**		**4.5**	**5.1**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.11		0.23	0.06		0.11
T	0.23		0.47	0.11		0.23
IT	0.32		0.66	0.16		0.32

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.8. Effect of treated paperboard mill effluent irrigation and solid waste on fruit length and girth (cm) of brinjal

Treatments	Length			Girth		
	I_1	I_2	Mean	I_1	I_2	Mean
T_1	6.5	6.7	**6.6**	9.8	10.5	**10.2**
T_2	7.3	7.2	**7.3**	12.4	9.8	**11.1**
T_3	7.1	8.2	**7.6**	9.7	13.2	**11.5**
T_4	7.8	7.6	**7.7**	12.2	12.5	**12.4**
T_5	7.2	8.2	**7.7**	12.3	14.7	**13.5**
T_6	7.4	7.4	**7.4**	11.5	12.4	**11.9**
T_7	8.0	10.2	**9.1**	14.5	15.2	**14.9**
T_8	9.1	10.1	**9.6**	14.2	15.8	**15.0**
Mean	**7.55**	**8.20**		**12.08**	**13.01**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.09		0.19	0.15		0.30
T	0.19		0.38	0.30		0.60
IT	0.26		0.53	0.42		0.85

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.9. Effect of treated paperboard mill effluent irrigation and solid waste on yield (t ha^{-1}) of chillies and brinjal

Treatments	Chillies			Brinjal		
	I_1	I_2	Mean	I_1	I_2	Mean
T_1	10.04	11.21	**10.63**	21.78	23.21	**22.50**
T_2	11.11	12.23	**11.67**	23.34	25.28	**24.31**
T_3	10.12	11.78	**10.95**	22.96	23.76	**23.36**
T_4	10.98	12.75	**11.87**	24.76	25.21	**24.99**
T_5	11.47	12.48	**11.98**	23.84	26.27	**25.06**
T_6	10.98	11.24	**11.11**	21.21	23.24	**22.23**
T_7	11.42	13.12	**12.27**	25.28	26.17	**25.73**
T_8	12.62	14.27	**13.45**	25.97	28.41	**27.19**
Mean	**11.1**	**12.4**		**23.6**	**25.2**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.10		0.21	0.07		0.14
T	0.21		0.43	0.14		0.28
IT	0.29		0.60	0.19		0.39

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.10. Effect of treated paperboard mill effluent irrigation and solid waste on soil pH

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	7.21	7.26	**7.24**	7.28	7.35	**7.32**	7.37	7.48	**7.43**	7.24	7.31	**7.28**	7.41	7.52	**7.47**	7.47	7.67	**7.57**
T_2	7.44	7.47	**7.46**	7.46	7.52	**7.49**	7.64	7.67	**7.66**	7.44	7.47	**7.46**	7.52	7.65	**7.59**	7.68	7.82	**7.75**
T_3	7.52	7.57	**7.55**	7.60	7.64	**7.62**	7.72	7.82	**7.77**	7.52	7.55	**7.54**	7.63	7.71	**7.67**	7.72	7.94	**7.83**
T_4	7.24	7.48	**7.36**	7.52	7.56	**7.54**	7.53	7.62	**7.58**	7.48	7.49	**7.49**	7.57	7.61	**7.59**	7.64	7.85	**7.75**
T_5	7.33	7.35	**7.34**	7.46	7.49	**7.48**	7.49	7.53	**7.51**	7.33	7.44	**7.39**	7.51	7.63	**7.57**	7.58	7.79	**7.69**
T_6	7.49	7.51	**7.50**	7.61	7.58	**7.60**	7.71	7.73	**7.72**	7.49	7.51	**7.50**	7.53	7.63	**7.58**	7.61	7.87	**7.74**
T_7	7.23	7.31	**7.27**	7.42	7.46	**7.44**	7.49	7.61	**7.55**	7.24	7.52	**7.38**	7.48	7.59	**7.54**	7.62	7.86	**7.40**
T_8	7.25	7.28	**7.27**	7.35	7.46	**7.41**	7.42	7.59	**7.51**	7.32	7.38	**7.35**	7.46	7.57	**7.52**	7.55	7.72	**7.64**
Mean	**7.34**	**7.40**		**7.46**	**7.51**		**7.55**	**7.63**		**7.38**	**7.46**		**7.51**	**7.61**		**7.61**	**7.82**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.02		0.04	0.02		0.04	0.02		0.05	0.02		0.04	0.02		0.05	0.02		0.05
T	0.04		0.08	0.04		0.09	0.04		0.09	0.04		0.08	0.04		0.09	0.05		0.09
IT	0.06		NS	0.06		NS	0.06		NS	0.06		0.12	0.06		NS	0.06		NS

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.11. Effect of treated paperboard mill effluent irrigation and solid waste on EC (dS m^{-1}) of soil

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	0.33	0.37	**0.35**	0.39	0.42	**0.41**	0.45	0.47	**0.46**	0.36	0.39	**0.38**	0.43	0.45	**0.44**	0.47	0.50	**0.49**
T_2	0.48	0.53	**0.51**	0.52	0.56	**0.54**	0.53	0.58	**0.56**	0.49	0.45	**0.47**	0.51	0.54	**0.53**	0.54	0.57	**0.56**
T_3	0.51	0.52	**0.52**	0.53	0.54	**0.54**	0.55	0.61	**0.58**	0.51	0.53	**0.52**	0.53	0.55	**0.54**	0.56	0.62	**0.59**
T_4	0.48	0.50	**0.49**	0.50	0.56	**0.53**	0.48	0.54	**0.51**	0.50	0.52	**0.51**	0.51	0.53	**0.52**	0.54	0.58	**0.56**
T_5	0.44	0.48	**0.46**	0.47	0.51	**0.49**	0.51	0.54	**0.53**	0.45	0.50	**0.48**	0.46	0.52	**0.49**	0.51	0.57	**0.54**
T_6	0.49	0.52	**0.51**	0.52	0.54	**0.53**	0.55	0.59	**0.57**	0.46	0.48	**0.47**	0.51	0.54	**0.53**	0.53	0.59	**0.56**
T_7	0.42	0.44	**0.43**	0.46	0.48	**0.47**	0.49	0.52	**0.51**	0.45	0.46	**0.46**	0.48	0.51	**0.50**	0.51	0.54	**0.53**
T_8	0.37	0.41	**0.39**	0.42	0.43	**0.43**	0.46	0.48	**0.47**	0.39	0.42	**0.41**	0.46	0.49	**0.48**	0.49	0.52	**0.51**
Mean	**0.44**	**0.47**		**0.48**	**0.50**		**0.50**	**0.54**		**0.46**	**0.48**		**0.50**	**0.52**		**0.53**	**0.57**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.004	0.008		0.002	0.004		0.005	0.010		0.002	0.003		0.002	0.005		0.003	0.005	
T	0.008	0.016		0.004	0.009		0.010	0.021		0.003	0.007		0.005	0.010		0.005	0.011	
IT	0.011	NS		0.006	0.012		0.014	NS		0.005	0.010		0.007	NS		0.008	NS	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.12. Effect of treated paperboard mill effluent irrigation and solid waste on organic carbon content (per cent) of soil

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	0.33	0.42	**0.38**	0.40	0.46	**0.43**	0.41	0.49	**0.45**	0.33	0.41	**0.37**	0.39	0.42	**0.41**	0.41	0.48	**0.45**
T_2	0.36	0.50	**0.43**	0.43	0.55	**0.49**	0.48	0.58	**0.53**	0.47	0.53	**0.50**	0.50	0.55	**0.53**	0.53	0.57	**0.55**
T_3	0.32	0.44	**0.38**	0.38	0.50	**0.44**	0.42	0.53	**0.48**	0.45	0.50	**0.48**	0.46	0.52	**0.49**	0.51	0.57	**0.54**
T_4	0.39	0.49	**0.44**	0.45	0.53	**0.49**	0.52	0.55	**0.54**	0.45	0.48	**0.47**	0.49	0.50	**0.50**	0.52	0.52	**0.52**
T_5	0.38	0.51	**0.45**	0.46	0.57	**0.51**	0.53	0.62	**0.58**	0.53	0.55	**0.54**	0.54	0.57	**0.56**	0.55	0.59	**0.57**
T_6	0.41	0.49	**0.45**	0.47	0.52	**0.50**	0.55	0.55	**0.55**	0.49	0.53	**0.51**	0.51	0.55	**0.53**	0.53	0.59	**0.56**
T_7	0.4	0.53	**0.47**	0.48	0.58	**0.53**	0.57	0.61	**0.59**	0.52	0.52	**0.52**	0.55	0.54	**0.55**	0.57	0.6	**0.59**
T_8	0.42	0.54	**0.48**	0.49	0.60	**0.55**	0.58	0.64	**0.61**	0.55	0.55	**0.55**	0.57	0.58	**0.58**	0.58	0.62	**0.60**
Mean	**0.38**	**0.49**		**0.44**	**0.54**		**0.51**	**0.57**		**0.47**	**0.51**		**0.50**	**0.53**		**0.53**	**0.57**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.004	0.008		0.005	0.009		0.005	0.011		0.005	0.010		0.005	0.011		0.003	0.006	
T	0.008	0.015		0.009	0.019		0.011	0.022		0.009	0.019		0.010	0.021		0.006	0.011	
IT	0.011	0.022		0.013	0.027		0.015	0.031		0.013	0.027		0.015	0.030		0.008	0.016	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.13. Effect of treated paperboard mill effluent irrigation and solid waste on soil available N content (kg ha^{-1})

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	132	139	**136**	141	145	**143**	122	128	**125**	135	138	**137**	142	148	**145**	137	143	**140**
T_2	147	152	**150**	154	159	**157**	136	144	**140**	139	144	**142**	144	153	**149**	140	148	**144**
T_3	136	140	**138**	142	148	**145**	126	132	**129**	143	146	**145**	152	155	**154**	148	150	**149**
T_4	149	155	**152**	156	161	**159**	131	141	**136**	149	156	**153**	164	167	**166**	159	163	**161**
T_5	160	168	**164**	163	181	**172**	148	167	**158**	159	165	**162**	161	177	**169**	156	169	**163**
T_6	151	157	**154**	159	164	**162**	139	144	**142**	151	157	**154**	165	169	**167**	160	164	**162**
T_7	163	179	**171**	171	188	**180**	152	169	**161**	167	178	**173**	178	192	**185**	152	167	**160**
T_8	171	192	**182**	178	196	**187**	155	176	**166**	169	180	**175**	185	195	**190**	180	189	**185**
Mean	**151**	**160**		**158**	**168**		**139**	**150**		**152**	**158**		**161**	**170**		**154**	**162**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	3.72	7.60		3.41	6.97		3.95	8.07		2.14	4.37		3.47	7.09		1.87	3.82	
T	7.44	15.19		6.82	13.93		7.90	16.14		4.28	8.74		6.94	14.17		3.74	7.64	
IT	10.52	NS		9.65	NS		11.17	NS		6.05	NS		9.82	NS		5.29	NS	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,

T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.14. Effect of treated paperboard mill effluent irrigation and solid waste on soil available P content (kg ha^{-1})

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	19.89	19.87	**19.88**	20.07	21.78	**20.93**	19.81	20.93	**20.37**	20.13	21.24	**20.69**	20.52	21.34	**20.93**	19.24	19.81	**19.53**
T_2	20.16	21.30	**20.73**	21.30	22.76	**22.03**	21.02	21.27	**21.15**	20.88	21.62	**21.25**	21.88	21.95	**21.92**	19.85	20.58	**20.22**
T_3	20.22	21.58	**20.90**	21.58	23.27	**22.43**	21.72	21.56	**21.64**	20.45	21.86	**21.16**	20.92	22.64	**21.78**	19.36	19.71	**19.54**
T_4	20.26	21.86	**21.06**	21.86	23.01	**22.44**	21.21	22.56	**21.89**	22.51	23.16	**22.84**	22.77	23.98	**23.38**	20.00	21.17	**20.59**
T_5	21.21	22.58	**21.90**	22.58	23.53	**23.06**	21.93	22	**21.97**	23.72	25.55	**24.64**	23.94	25.72	**24.83**	22.28	24.12	**23.20**
T_6	20.81	20.86	**20.84**	20.86	23.77	**22.32**	21.72	21.87	**21.80**	22.69	24.33	**23.51**	23.00	24.68	**23.84**	19.42	22.25	**20.84**
T_7	21.36	23.42	**22.39**	23.42	24.25	**23.84**	22.47	23.58	**23.03**	24.10	26.84	**25.47**	24.68	27.21	**25.95**	21.42	25.16	**23.29**
T_8	22.83	24.86	**23.85**	24.86	25.92	**25.39**	22.87	23.97	**23.42**	25.93	28.21	**27.07**	26.24	28.33	**27.29**	23.42	27.42	**25.42**
Mean	**20.84**	**22.04**		**22.07**	**23.54**		**21.59**	**22.22**		**22.55**	**24.10**		**22.99**	**24.48**		**20.62**	**22.53**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.19	0.39		0.20	0.41		0.20	0.40		0.33	0.66		0.50	1.02		0.25	0.52	
T	0.38	0.78		0.41	0.83		0.39	0.80		0.65	1.33		1.00	2.03		0.51	1.03	
IT	0.54	NS		0.57	NS		0.55	NS		0.92	NS		1.41	NS		0.71	NS	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.15. Effect of treated paperboard mill effluent irrigation and solid waste on soil available K content (kg ha^{-1})

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	214	229	**222**	217	231	**224**	203	214	**209**	211	228	**220**	216	231	**224**	205	213	**209**
T_2	231	235	**233**	236	249	**243**	225	231	**228**	228	241	**235**	235	244	**240**	218	227	**223**
T_3	219	231	**225**	225	232	**229**	212	217	**215**	213	230	**222**	226	235	**231**	209	216	**213**
T_4	234	255	**245**	241	257	**249**	226	241	**234**	231	248	**240**	239	252	**246**	222	238	**230**
T_5	246	261	**254**	253	264	**259**	234	255	**245**	243	262	**253**	251	267	**259**	234	254	**244**
T_6	236	250	**243**	243	252	**248**	226	232	**229**	235	252	**244**	243	255	**249**	223	238	**231**
T_7	252	264	**258**	259	269	**264**	243	248	**246**	246	263	**255**	253	268	**261**	236	251	**244**
T_8	265	279	**272**	268	282	**275**	254	266	**260**	259	277	**268**	264	282	**273**	248	255	**252**
Mean	**237**	**251**		**243**	**255**		**228**	**238**		**233**	**250**		**241**	**254**		**224**	**237**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	5.09	10.40		5.81	11.86		4.88	9.96		5.02	10.26		5.57	11.37		5.96	12.18	
T	10.19	20.81		11.61	23.72		9.76	19.92		10.05	20.52		11.13	22.74		11.93	24.36	
IT	14.41	NS		16.42	NS		13.80	NS		14.21	NS		15.75	NS		16.87	NS	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.16. Effect of treated paperboard mill effluent irrigation and solid waste on exchangeable Ca content of soil (cmol (p^+) kg^{-1})

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	7.42	7.65	**7.54**	7.65	7.85	**7.75**	7.78	7.98	**7.88**	7.65	7.86	**7.76**	7.87	7.91	**7.89**	8.15	8.36	**8.26**
T_2	7.60	8.11	**7.86**	7.71	8.29	**8.00**	7.82	8.39	**8.11**	7.92	7.95	**7.94**	7.95	8.11	**8.03**	8.42	8.45	**8.44**
T_3	7.53	8.02	**7.78**	7.73	8.22	**7.98**	7.85	8.42	**8.14**	7.78	7.83	**7.81**	7.88	7.93	**7.91**	8.31	8.65	**8.48**
T_4	7.72	8.38	**8.05**	7.95	8.52	**8.24**	8.63	8.72	**8.68**	7.95	8.31	**8.13**	7.99	8.65	**8.32**	8.45	8.81	**8.63**
T_5	8.40	8.50	**8.45**	8.34	8.62	**8.48**	8.78	8.88	**8.83**	8.17	8.45	**8.31**	8.45	8.72	**8.59**	8.67	8.95	**8.81**
T_6	7.93	8.13	**8.03**	8.07	8.25	**8.16**	8.29	8.46	**8.38**	7.87	7.92	**7.90**	8.28	8.35	**8.32**	8.37	8.42	**8.40**
T_7	8.27	8.42	**8.35**	8.36	8.71	**8.54**	8.75	8.91	**8.83**	8.28	8.49	**8.39**	8.65	8.78	**8.72**	8.78	8.99	**8.89**
T_8	8.32	8.91	**8.62**	8.44	8.98	**8.71**	8.81	9.03	**8.92**	8.43	8.62	**8.53**	8.76	8.94	**8.85**	8.93	9.12	**9.03**
Mean	**7.90**	**8.27**		**8.03**	**8.43**		**8.34**	**8.60**		**8.01**	**8.22**		**8.23**	**8.42**		**8.51**	**8.72**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.09	0.19		0.10	0.20		0.10	0.20		0.02	0.05		0.07	0.15		0.10	0.20	
T	0.19	0.38		0.19	0.39		0.20	0.40		0.05	0.09		0.15	0.30		0.20	0.41	
IT	0.27	NS		0.27	NS		0.28	NS		0.06	0.13		0.21	NS		0.28	NS	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.17. Effect of treated paperboard mill effluent irrigation and solid waste on soil exchangeable Mg content (cmol (p^+) kg^{-1})

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	3.64	3.79	**3.72**	3.72	3.84	**3.78**	3.91	4.02	**3.97**	3.52	3.61	**3.57**	3.75	3.86	**3.81**	3.93	4.08	**4.01**
T_2	4.15	4.54	**4.35**	4.29	4.67	**4.48**	4.38	4.78	**4.58**	4.27	4.38	**4.33**	4.41	4.54	**4.48**	4.65	4.72	**4.69**
T_3	3.79	4.17	**3.98**	3.85	4.25	**4.05**	3.96	4.32	**4.14**	3.68	3.72	**3.70**	3.89	3.95	**3.92**	4.02	4.12	**4.07**
T_4	4.09	4.25	**4.17**	4.21	4.55	**4.38**	4.32	4.63	**4.48**	4.12	4.21	**4.17**	4.36	4.37	**4.37**	4.52	4.63	**4.58**
T_5	4.45	4.52	**4.49**	4.45	4.59	**4.52**	4.72	4.92	**4.82**	4.31	4.33	**4.32**	4.62	4.83	**4.73**	4.86	5.11	**4.99**
T_6	4.11	4.35	**4.23**	4.32	4.36	**4.34**	4.47	4.68	**4.58**	4.28	4.32	**4.30**	4.85	4.61	**4.73**	4.71	4.85	**4.78**
T_7	4.51	4.79	**4.65**	4.72	4.84	**4.78**	4.83	4.95	**4.89**	4.59	4.72	**4.66**	4.81	4.98	**4.90**	4.95	5.18	**5.07**
T_8	4.63	4.93	**4.78**	4.78	4.91	**4.85**	4.95	5.12	**5.04**	4.62	4.81	**4.72**	4.92	5.22	**5.07**	5.05	5.27	**5.16**
Mean	**4.17**	**4.42**		**4.29**	**4.50**		**4.44**	**4.62**		**4.17**	**4.26**		**4.45**	**4.55**		**4.59**	**4.75**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.02	0.05		0.04	0.08		0.04	0.08		0.04	0.08		0.04	0.08		0.04	0.09	
T	0.05	0.10		0.08	0.16		0.08	0.16		0.08	0.15		0.08	0.16		0.08	0.17	
IT	0.07	0.14		0.11	0.23		0.11	0.23		0.11	NS		0.11	NS		0.12	NS	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.18. Effect of treated paperboard mill effluent irrigation and solid waste on soil exchangeable Na content (cmol (p^+) kg^{-1})

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	1.58	1.67	**1.63**	1.69	1.83	**1.76**	1.81	1.92	**1.87**	1.51	1.73	**1.62**	1.69	1.78	**1.74**	1.77	1.87	**1.82**
T_2	1.48	1.54	**1.51**	1.63	1.73	**1.68**	1.71	1.85	**1.78**	1.48	1.64	**1.56**	1.61	1.67	**1.64**	1.65	1.75	**1.70**
T_3	1.52	1.59	**1.56**	1.67	1.81	**1.74**	1.73	1.87	**1.80**	1.49	1.65	**1.57**	1.62	1.72	**1.67**	1.68	1.76	**1.72**
T_4	1.42	1.51	**1.47**	1.55	1.69	**1.62**	1.61	1.75	**1.68**	1.47	1.53	**1.50**	1.52	1.61	**1.57**	1.61	1.69	**1.65**
T_5	1.39	1.45	**1.42**	1.51	1.65	**1.58**	1.58	1.71	**1.65**	1.49	1.51	**1.50**	1.51	1.54	**1.53**	1.63	1.64	**1.64**
T_6	1.46	1.55	**1.51**	1.62	1.79	**1.71**	1.69	1.78	**1.74**	1.44	1.59	**1.52**	1.56	1.59	**1.58**	1.59	1.69	**1.64**
T_7	1.24	1.36	**1.30**	1.47	1.62	**1.55**	1.55	1.69	**1.62**	1.37	1.45	**1.41**	1.42	1.48	**1.45**	1.55	1.60	**1.58**
T_8	1.22	1.31	**1.27**	1.44	1.59	**1.52**	1.49	1.63	**1.56**	1.24	1.36	**1.30**	1.42	1.49	**1.46**	1.44	1.57	**1.51**
Mean	**1.41**	**1.50**		**1.57**	**1.71**		**1.65**	**1.78**		**1.44**	**1.56**		**1.54**	**1.61**		**1.62**	**1.70**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.008		0.017	0.009		0.018	0.009		0.019	0.008		0.017	0.018		0.037	0.009		0.019
T	0.016		0.033	0.018		0.037	0.019		0.039	0.017		0.034	0.036		0.074	0.018		0.037
IT	0.023		NS	0.025		NS	0.027		NS	0.024		NS	0.051		NS	0.026		NS

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,

T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.19. Effect of treated paperboard mill effluent irrigation and solid waste on soil exchangeable K content (cmol (p^+) kg^{-1})

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	0.08	0.14	**0.11**	0.12	0.18	**0.15**	0.16	0.19	**0.18**	0.12	0.17	**0.15**	0.15	0.19	**0.17**	0.16	0.21	**0.19**
T_2	0.09	0.16	**0.12**	0.15	0.2	**0.18**	0.19	0.22	**0.21**	0.15	0.2	**0.18**	0.17	0.23	**0.20**	0.2	0.25	**0.23**
T_3	0.17	0.19	**0.18**	0.22	0.24	**0.23**	0.24	0.26	**0.25**	0.13	0.19	**0.16**	0.15	0.21	**0.18**	0.18	0.22	**0.20**
T_4	0.13	0.17	**0.15**	0.17	0.22	**0.20**	0.20	0.22	**0.21**	0.18	0.24	**0.21**	0.21	0.29	**0.25**	0.22	0.35	**0.29**
T_5	0.18	0.2	**0.19**	0.2	0.25	**0.23**	0.26	0.27	**0.27**	0.23	0.29	**0.26**	0.25	0.35	**0.30**	0.29	0.39	**0.34**
T_6	0.15	0.18	**0.17**	0.18	0.21	**0.20**	0.22	0.24	**0.23**	0.19	0.22	**0.21**	0.22	0.27	**0.25**	0.25	0.29	**0.27**
T_7	0.19	0.2	**0.20**	0.21	0.26	**0.24**	0.26	0.27	**0.27**	0.24	0.31	**0.28**	0.28	0.38	**0.33**	0.32	0.41	**0.37**
T_8	0.21	0.23	**0.22**	0.23	0.29	**0.26**	0.28	0.30	**0.29**	0.27	0.35	**0.31**	0.31	0.41	**0.36**	0.38	0.49	**0.44**
Mean	**0.15**	**0.18**		**0.19**	**0.23**		**0.23**	**0.25**		**0.19**	**0.25**		**0.22**	**0.29**		**0.25**	**0.33**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.005		0.011	0.003		0.006	0.004		0.008	0.002		0.006	0.003		0.006	0.004		0.008
T	0.011		0.022	0.006		0.012	0.008		0.016	0.005		0.012	0.006		0.012	0.008		0.017
IT	0.015		NS	0.008		0.017	0.011		NS	0.008		0.016	0.008		0.017	0.012		0.024

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.20. Effect of treated paperboard mill effluent irrigation and solid waste on CEC of soil (cmol (p$^+$) kg^{-1})

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	12.71	13.74	**13.23**	13.97	14.01	**13.99**	13.92	14.44	**14.18**	13.38	13.84	**13.61**	13.86	14.17	**14.02**	14.53	15.07	**14.80**
T_2	13.58	15.11	**14.35**	14.60	15.77	**15.19**	14.59	15.71	**15.15**	14.47	15.23	**14.85**	14.87	15.24	**15.06**	15.75	15.91	**15.83**
T_3	13.08	14.59	**13.84**	14.23	15.25	**14.74**	14.28	15.39	**14.84**	13.76	14.43	**14.10**	14.14	14.39	**14.27**	14.91	15.44	**15.18**
T_4	13.71	15.16	**14.44**	14.84	15.91	**15.38**	15.38	15.79	**15.59**	14.57	15.35	**14.96**	14.88	15.06	**14.97**	15.65	16.33	**15.99**
T_5	14.86	15.61	**15.24**	15.74	16.37	**16.06**	16.05	16.37	**16.21**	15.21	15.73	**15.47**	15.33	15.93	**15.63**	16.32	17.05	**16.69**
T_6	14.00	15.06	**14.53**	15.19	15.78	**15.49**	15.16	15.68	**15.42**	14.83	15.23	**15.03**	15.37	15.39	**15.38**	15.77	16.10	**15.94**
T_7	14.84	15.85	**15.35**	15.92	16.58	**16.25**	16.10	16.69	**16.40**	15.53	16.24	**15.89**	15.58	16.14	**15.86**	16.58	17.19	**16.89**
T_8	15.09	16.59	**15.84**	16.16	17.07	**16.62**	16.38	17.03	**16.71**	15.69	16.72	**16.21**	15.85	16.65	**16.25**	16.98	17.60	**17.29**
Mean	**13.98**	**15.21**		**15.08**	**15.84**		**15.23**	**15.89**		**14.68**	**15.35**		**14.99**	**15.37**		**15.81**	**16.34**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.17	0.35		0.18	0.37		0.18	0.37		0.18	0.36		0.18	0.36		0.19	0.38	
T	0.34	0.69		0.36	0.73		0.36	0.74		0.35	0.71		0.35	0.72		0.37	0.76	
IT	0.48	NS		0.51	NS		0.51	NS		0.49	NS		0.50	NS		0.53	NS	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.21. Effect of treated paperboard mill effluent irrigation and solid waste on soil ESP

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	**Mean**	I_1	I_2	**Mean**	I_1	I_2	**Mean**	I_1	I_2	**Mean**	I_1	I_2	**Mean**	I_1	I_2	**Mean**
T_1	10.29	10.43	**10.36**	10.66	11.34	**11.00**	11.15	11.35	**11.25**	10.12	10.41	**10.27**	10.45	10.48	**10.47**	10.52	10.50	**10.51**
T_2	10.03	10.24	**10.14**	10.49	10.92	**10.70**	10.75	11.20	**10.98**	10.02	10.16	**10.09**	10.25	10.40	**10.33**	10.40	10.36	**10.38**
T_3	10.07	10.47	**10.27**	10.46	10.72	**10.59**	11.05	11.27	**11.16**	10.09	10.32	**10.21**	10.22	10.59	**10.41**	10.42	10.63	**10.53**
T_4	9.96	10.36	**10.16**	10.44	10.62	**10.53**	10.47	11.08	**10.78**	10.13	10.19	**10.16**	10.21	10.26	**10.24**	10.43	10.42	**10.43**
T_5	9.87	9.96	**9.92**	10.36	10.57	**10.46**	10.65	11.30	**10.98**	10.04	10.24	**10.14**	10.15	10.33	**10.24**	10.29	10.62	**10.46**
T_6	9.53	9.60	**9.57**	10.31	11.35	**10.83**	10.70	11.29	**11.00**	10.03	10.12	**10.08**	10.11	10.22	**10.17**	10.35	10.31	**10.33**
T_7	9.60	10.24	**9.92**	10.33	10.62	**10.48**	10.85	10.98	**10.92**	9.96	10.05	**10.01**	10.04	10.28	**10.16**	10.08	10.50	**10.29**
T_8	9.32	9.48	**9.40**	10.34	10.46	**10.40**	10.83	10.88	**10.86**	9.27	9.83	**9.55**	10.15	10.19	**10.17**	10.18	10.24	**10.21**
Mean	**9.83**	**10.10**		**10.42**	**10.83**		**10.81**	**11.17**		**9.96**	**10.17**		**10.20**	**10.34**		**10.33**	**10.45**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.21		NS	0.22		NS	0.23		NS	0.21		NS	0.22		NS	0.21		NS
T	0.41		NS	0.44		NS	0.45		NS	0.41		NS	0.43		NS	0.43		NS
IT	0.58		NS	0.62		NS	0.64		NS	0.58		NS	0.61		NS	0.60		NS

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.22. Effect of treated paperboard mill effluent irrigation and solid waste on soil bacterial population (x 10^6 CFU g^{-1} of soil)

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	18.0	20.7	**19.3**	30.0	30.3	**30.2**	35.3	38.3	**36.8**	18.3	19.3	**18.8**	29.0	29.0	**29.0**	33.0	34.7	**33.8**
T_2	23.0	24.0	**23.5**	37.7	38.7	**38.2**	42.7	43.7	**43.2**	23.0	24.0	**23.5**	38.0	38.7	**38.3**	40.3	41.0	**40.7**
T_3	22.3	24.7	**23.5**	33.7	35.7	**34.7**	39.7	41.7	**40.7**	23.0	23.7	**23.3**	33.0	34.0	**33.5**	34.0	38.0	**36**
T_4	25.0	26.0	**25.5**	40.3	42.7	**41.5**	48.3	49.3	**48.8**	24.3	27.0	**25.7**	39.0	39.7	**39.3**	42.0	45.3	**43.7**
T_5	32.3	33.3	**32.8**	43.7	44.7	**44.2**	51.3	53.0	**52.2**	35.0	36.0	**35.5**	42.7	44.0	**43.3**	45.3	48.3	**46.8**
T_6	31.7	33.0	**32.3**	34.7	36.3	**35.5**	40.7	42.7	**41.7**	31.0	32.0	**31.5**	34.0	34.0	**34.0**	39.0	39.7	**39.3**
T_7	34.3	36.7	**35.5**	44.3	46.3	**45.3**	53.0	57.0	**55.0**	36.0	37.7	**36.8**	44.3	46.7	**45.5**	48.3	54.3	**51.3**
T_8	47.3	49.3	**48.3**	52.7	55.7	**54.2**	62.3	66.0	**64.2**	46.0	51.3	**48.7**	51.0	58.3	**54.7**	59.0	63.0	**61.0**
Mean	**29.2**	**31.0**		**39.6**	**41.3**		**46.7**	**49.0**		**29.6**	**31.4**		**38.9**	**40.5**		**42.6**	**45.5**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.12		0.24	0.16		0.33	0.23		0.46	0.29		0.59	0.38		0.78	0.42		0.86
T	0.23		0.48	0.32		0.65	0.45		0.93	0.58		1.19	0.76		1.55	0.84		1.72
IT	0.33		0.67	0.45		0.92	0.64		1.31	0.82		1.68	1.07		2.19	1.19		2.44

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.23. Effect of treated paperboard mill effluent irrigation and solid waste on soil fungal population (x 10^4 CFU g^{-1} of soil)

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	5.0	7.0	**6.0**	7.0	10.7	**8.8**	8.0	11.7	**9.8**	5.0	6.0	**5.5**	6.0	7.0	**6.5**	7.0	8.0	**7.5**
T_2	9.0	9.0	**9.0**	12.7	13.0	**12.8**	13.0	14.7	**13.8**	8.0	10.0	**9.0**	11.0	11.7	**11.3**	12.0	12.7	**12.3**
T_3	6.0	8.0	**7.0**	8.0	11.3	**9.70**	9.0	12.0	**10.5**	6.0	8.0	**7.0**	7.0	8.3	**7.7**	8.0	9.7	**8.8**
T_4	9.7	10.0	**9.8**	13.3	14.7	**14.0**	14.7	16.3	**15.5**	9.0	11.3	**10.2**	12.0	13.0	**12.5**	13.0	14.3	**13.7**
T_5	17.0	17.7	**17.3**	18.7	19.0	**18.8**	19.3	20.3	**19.8**	17.0	18.7	**17.8**	18.3	20.7	**19.5**	20.3	21.3	**20.8**
T_6	14.7	15.3	**15.0**	15.0	18.7	**16.8**	15.3	19.3	**17.3**	16.0	16.7	**16.3**	17.7	18.0	**17.8**	18.7	18.7	**18.7**
T_7	17.3	17.7	**17.5**	19.3	20.3	**19.8**	19.7	21.7	**20.7**	17.3	18.7	**18.0**	18.7	20.7	**19.7**	20.7	22.3	**21.5**
T_8	18.7	20.3	**19.5**	21.7	22.3	**22.0**	22.3	24.3	**23.3**	19.0	20.7	**19.8**	20.3	22.7	**21.5**	22.3	24.7	**23.5**
Mean	**12.2**	**13.1**		**14.5**	**16.3**		**15.2**	**17.5**		**12.2**	**13.8**		**13.9**	**15.3**		**15.3**	**16.5**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.12	0.24		0.16	0.33		0.23	0.46		0.10	0.21		0.13	0.26		0.13	0.27	
T	0.23	0.48		0.32	0.65		0.45	0.93		0.20	0.42		0.25	0.51		0.26	0.54	
IT	0.33	0.67		0.45	0.92		0.64	1.31		0.29	0.59		0.35	0.72		0.37	0.76	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.24. Effect of treated paperboard mill effluent irrigation and solid waste on soil actinomycetes population (x 10^3 g^{-1} of soil)

Treatments	Chillies									Brinjal								
	45 DAT			90 DAT			Harvest			45 DAT			90 DAT			Harvest		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	3.3	4.0	**3.7**	6.0	7.0	**6.5**	7.0	7.0	**7.0**	4.0	4.3	**4.2**	5.0	5.7	**5.3**	6.0	7.7	**6.8**
T_2	5.3	6.0	**5.7**	7.7	8.0	**7.8**	8.0	9.0	**8.5**	5.3	6.0	**5.7**	6.7	7.0	**6.8**	7.3	9.0	**8.2**
T_3	4.0	5.0	**4.5**	6.7	7.0	**6.8**	7.7	8.0	**7.8**	4.0	5.7	**4.8**	6.0	7.3	**6.7**	7.0	8.3	**7.7**
T_4	6.0	6.0	**6.0**	8.0	9.0	**8.5**	9.0	9.7	**9.3**	7.0	7.0	**7.0**	8.0	8.7	**8.3**	8.7	9.7	**9.2**
T_5	7.7	8.0	**7.8**	8.7	12.0	**10.3**	10.0	11.7	**10.8**	8.0	8.3	**8.2**	10.0	9.3	**9.7**	11.0	11.3	**11.2**
T_6	6.3	7.0	**6.7**	9.0	8.0	**8.5**	9.0	10.7	**9.8**	7.3	7.3	**7.3**	9.7	10.0	**9.8**	10.3	11.0	**10.7**
T_7	7.0	8.0	**7.5**	10.7	12.0	**11.3**	12.0	15.0	**13.5**	9.0	11.0	**10.0**	11.0	11.7	**11.3**	12.0	14.3	**13.2**
T_8	8.0	10.3	**9.2**	13.0	14.3	**13.7**	15.0	19.0	**17.0**	11.0	13.3	**12.2**	12.3	14.0	**13.2**	13.3	16.3	**14.8**
Mean	**6.0**	**6.8**		**8.7**	**9.7**		**9.7**	**11.3**		**7.0**	**7.9**		**8.6**	**9.2**		**9.5**	**11.0**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.09	0.19		0.30	0.60		0.32	0.65		0.27	0.55		0.21	0.42		0.15	0.31	
T	0.19	0.39		0.59	1.21		0.63	1.29		0.54	1.10		0.41	0.84		0.31	0.63	
IT	0.27	0.55		0.83	NS		0.89	1.82		0.76	NS		0.58	NS		0.44	0.89	

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.25. Effect of treated paperboard mill effluent irrigation and solid waste on enzyme activity of chillies grown soil at harvest stage

Treatments	Urease activity (g of ammoniacal - N released kg^{-1} soil 24 h^{-1})			Phosphatase activity (μg PNPP g^{-1})			Dehydrogenase activity(μg TPF g^{-1} 24 h^{-1})		
	I_1	**I_2**	**Mean**	**I_1**	**I_2**	**Mean**	**I_1**	**I_2**	**Mean**
T_1	9.4	9.9	**9.7**	37.5	39.7	**38.6**	14.2	16.3	**15.3**
T_2	9.8	11.0	**10.4**	39.2	44.0	**41.6**	19.2	22.4	**20.8**
T_3	10.3	11.3	**10.8**	41.3	45.2	**43.3**	17.5	21.3	**19.4**
T_4	11.2	11.4	**11.3**	44.7	45.4	**45.1**	19.4	23.3	**21.3**
T_5	13.1	14.2	**13.7**	52.5	55.8	**54.2**	22.6	26.2	**24.4**
T_6	12.4	12.2	**12.3**	49.4	51.8	**50.6**	18.5	20.8	**19.7**
T_7	13.2	14.3	**13.7**	53.0	57.5	**55.2**	24.1	27.2	**25.7**
T_8	14.5	16.4	**15.5**	58.0	62.5	**60.3**	28.0	29.6	**28.8**
Mean	**11.7**	**12.6**		**47.0**	**50.2**		**20.4**	**23.4**	
	SEd	**CD(0.05)**		**SEd**	**CD(0.05)**		**SEd**	**CD(0.05)**	
I	0.11		0.22	0.14		0.28	0.20		0.41
T	0.21		0.44	0.27		0.55	0.40		0.81
IT	0.30		0.62	0.38		0.78	0.56		1.15

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.26. Effect of treated paperboard mill effluent irrigation and solid waste on enzyme activity of brinjal grown soil at harvest stage

Treatments	Urease activity (g of ammoniacal - N released kg^{-1} soil 24 h^{-1})			Phosphatase activity (μg PNPP g^{-1})			Dehydrogenase activity (μg TPF g^{-1} 24 h^{-1})		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	9.3	9.6	**9.5**	44.0	44.8	**44.4**	17.1	21.1	**19.1**
T_2	9.5	9.1	**9.3**	45.6	46.8	**46.2**	19.2	24.2	**21.7**
T_3	10.2	10.4	**10.3**	44.6	47.5	**46.0**	20.4	27.2	**23.8**
T_4	11.3	11.6	**11.4**	49.0	51.9	**50.4**	21.5	29.2	**25.4**
T_5	12.0	13.3	**12.6**	50.3	52.5	**51.4**	22.2	24.3	**23.3**
T_6	13.3	12.6	**13.0**	46.2	50.9	**48.6**	19.6	22.5	**21.0**
T_7	12.3	13.4	**12.9**	51.3	55.2	**53.3**	22.7	25.1	**23.9**
T_8	14.4	14.6	**14.5**	55.9	66.5	**61.2**	23.1	29.5	**26.3**
Mean	**11.5**	**11.8**		**48.4**	**52.0**		**20.7**	**25.4**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.11		0.22	0.45		0.91	0.21		0.42
T	0.22		0.44	0.90		1.83	0.41		0.84
IT	0.30		0.62	1.27		2.59	0.58		1.19

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.27. Effect of treated paperboard mill effluent irrigation and solid wastes on ascorbic acid, capsaicin and oleoresin content (mg 100 g^{-1}) of chillies

Treatments	Ascorbic acid			Capsaicin			Oleoresin		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	20.67	23.69	**22.18**	0.45	0.53	**0.49**	11.32	11.78	**11.55**
T_2	27.67	31.00	**29.34**	0.49	0.62	**0.56**	12.47	12.66	**12.57**
T_3	20.00	24.67	**22.34**	0.47	0.56	**0.52**	11.83	11.99	**11.91**
T_4	26.33	38.34	**32.34**	0.47	0.64	**0.56**	13.25	13.46	**13.36**
T_5	34.67	45.32	**40.00**	0.54	0.72	**0.63**	13.98	14.20	**14.09**
T_6	28.00	33.65	**30.83**	0.51	0.76	**0.64**	13.37	13.71	**13.54**
T_7	44.60	59.33	**51.97**	0.54	0.73	**0.64**	13.73	14.66	**14.19**
T_8	51.32	65.21	**58.27**	0.60	0.80	**0.70**	14.95	15.52	**15.23**
Mean	**31.66**	**40.15**		**0.51**	**0.67**		**13.11**	**13.50**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.34		0.68	0.01		0.03	0.04		0.08
T	0.67		1.37	0.02		0.05	0.07		0.15
IT	0.95		1.94	0.03		0.07	0.10		0.21

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.28. Effect of treated paperboard mill effluent irrigation and solid wastes on ascorbic acid (mg 100 g^{-1}) and phenol (μg g^{-1}) content of brinjal

Treatments	Ascorbic acid			Phenol		
	I_1	I_2	Mean	I_1	I_2	Mean
T_1	11.30	11.55	**11.43**	1016	1076	**1046**
T_2	11.52	11.62	**11.57**	1075	1112	**1094**
T_3	11.10	11.25	**11.17**	1049	1056	**1052**
T_4	12.08	12.21	**12.15**	1088	1095	**1091**
T_5	12.39	12.52	**12.46**	1125	1165	**1145**
T_6	12.25	12.36	**12.31**	1097	1132	**1114**
T_7	12.43	12.61	**12.52**	1129	1179	**1154**
T_8	12.52	12.84	**12.68**	1153	1225	**1189**
Mean	**11.9**	**12.00**		**1091**	**1130**	
	SEd		**CD(0.05)**	**SEd**		**CD(0.05)**
I	0.17		0.34	9.86		20.14
T	0.33		0.68	19.73		40.28
IT	0.47		0.95	27.90		NS

I_1 - Well water; I_2 -Treated effluent

T_1 – 100 % NPK, T_2 - FYM + 100 % NPK, T_3 - FA + 100 % NPK, T_4 - BM+ 100 % NPK,
T_5 – VC+ 100 % NPK, T_6 - BM + FA + 100 % NPK, T_7 - VC+ FA+ 100 % NPK, T_8 - BM+ VC+FA + 100 % NPK

(FYM – Farmyard manure ; FA – Fly ash ; BM– Biomanure ; VC– Vermicompost ; DAT- Days After Transplanting)

Table 4.2. Characteristics of solid wastes

Characters	Biomanure	Fly ash	FYM	VC
pH	7.83	8.21	7.62	7.65
EC (dS m^{-1})	1.26	0.98	0.83	1.31
OC (per cent)	24.7	-	22.5	25.1
Total N (per cent)	1.54	0.37	0.84	1.78
Total P (per cent)	0.63	0.21	0.53	0.69
Total K (per cent)	1.22	0.83	0.76	1.42
C: N ratio	16:1	-	34:1	14:1
Total Ca (per cent)	097	1.72	1.02	1.38
Total Mg (per cent)	0.28	0.79	0.37	0.92
Bacteria (x 10^6 CFU g^{-1})	37	-	32	45
Fungi (x 10^4 CFU g^{-1})	14	-	11	18
Actinomycetes (x 10^3 CFU g^{-1})	21	-	16	27

FYM – Farmyard manure, VC – Vermicompost

Table 4.3. Initial characteristics of treated effluent and well water used for irrigation

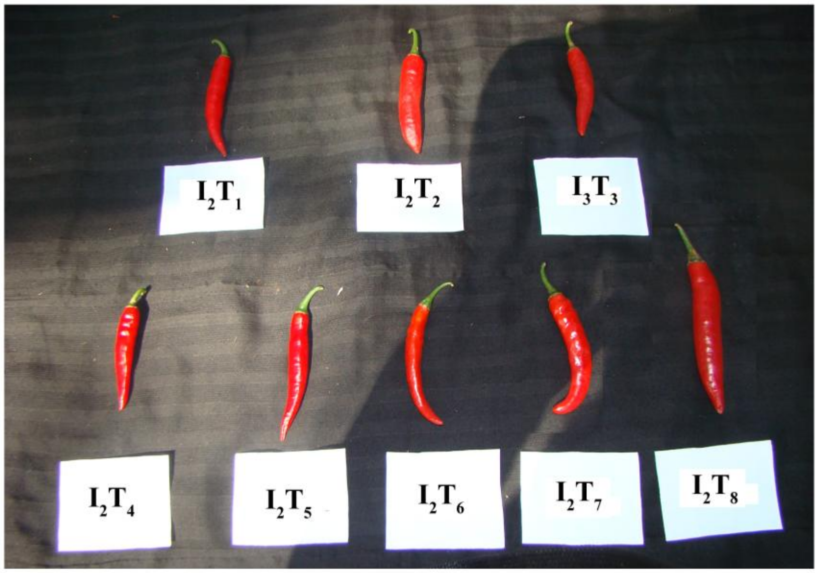
Characteristics	Treated effluent	Well water
Color	Colourless	Colourless
pH	7.10	7.20
EC (dS m^{-1})	1.42	0.43
Total dissolved solids (mg L^{-1})	980	236.2
Total suspended solids (mg L^{-1})	92	-
Dissolved oxygen (mg L^{-1})	4.8	5.6
BOD (mg L^{-1})	22.47	6.10
COD (mg L^{-1})	138.3	42.0
Organic carbon (per cent)	0.62	-
Calcium (mg L^{-1})	290	13.2
Magnesium (mg L^{-1})	92	7.1
Sodium (mg L^{-1})	122.0	12.35
Chloride (mg L^{-1})	424	61
Sulphate (mg L^{-1})	317	92
Carbonate (mg L^{-1})	48	27.57
Bicarbonate (mg L^{-1})	146.4	148.5
Ammoniacal nitrogen (mg L^{-1})	24.7	-
Phosphorus (mg L^{-1})	2.8	-
Potassium (mg L^{-1})	18.29	-
Bacteria (x 10^6 CFU ml^{-1})	24	7
Fungi (x 10^4 CFU ml^{-1})	7	3
Actinomycetes (x 10^3 CFU ml^{-1})	5	2

Table 4.1. Initial characteristics of experimental soil

Particulars	Chillies	Brinjal
Physical properties		
Bulk density (Mg m^{-3})	1.35	1.35
Particle density (Mg m^{-3})	2.21	2.20
Pore space (per cent)	18.95	18.94
Chemical properties		
pH	7.21	7.34
Electrical conductivity (dS m^{-1})	0.29	0.31
Organic carbon (per cent)	0.42	0.47
Available nitrogen (kg ha^{-1})	131	142
Available phosphorus (kg ha^{-1})	19.75	20.14
Available potassium (kg ha^{-1})	212	216
Exchangeable calcium (cmol (p^+) kg^{-1})	6.95	7.12
Exchangeable magnesium (cmol (p^+) kg^{-1})	3.48	3.57
Exchangeable sodium (cmol (p^+) kg^{-1})	1.62	1.76
Exchangeable potassium (cmol (p^+) kg^{-1})	0.08	0.14
CEC (cmol (p^+) kg^{-1})	12.13	12.59
ESP	13.35	13.97
Micrological properties		
Bacteria (x 10^6 CFU g^{-1} of soil)	16.0	18.3
Fungi (x 10^4 CFU g^{-1} of soil)	5.0	5.0
Actinomycetes (x 10^3 CFU g^{-1} of soil)	3.3	4.3

Plate 2. Effect of treated effluent and well water irrigation on chillies fruit size

a) Effluent irrigation



b) Well water irrigation

Plate 1. General view of field experiments

a) Chillies

b) Brinjal

Plate 3. Effect of treated effluent and well water irrigation on brinjal fruit size

a) Effluent irrigation

b) Well water irrigation