TR(BR) 141

IMPACT OF SEWAGE WASTE DISPOSAL ON SOIL STRATA AND GROUND WATER QUALITY

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667 (U.P.)
INDIA
1995-96

PREFACE

In recent years, an increasing threat to ground water pollution due to human activity has become of great importance. The adverse effects on ground water quality are the results of man's activity at ground surface, unintentionally by agriculture, domestic and industrial effluents, unexpectedly by sub-surface or surface disposal of sewage and industrial wastes.

Almost all major cities of the country are facing pollution problems. Enormous amount of sewage and industrial effluents are being discharged into the nearby land or water course without any treatment leading to ground water pollution.

A major problem in urbanized areas is the collection and disposal of domestic wastewater. Because a large volume of sewage is generated in a small area, the waste cannot be adequately disposed off by conventional septic tanks and cesspools.. Therefore, special disposal sites are being used to collect and dispose such wastes in densely populated areas. The Bharat Heavy Electricals Limited, Ranipur, Hardwar has constructed a sanitary sewer system to collect the sewage of the township at a central point and subsequently used over nearby land for irrigation.

In view of above, it is proposed to study the impact of land application of sewage waste on the soil strata and ground water quality of Bahadrabad area in district Hardwar. The proposed study will provide clear picture about the status of pollution due to the disposal of sewage waste on land, which will be useful for taking further action for proper waste management.

The report has been prepared by Dr. C. K. Jain, Sc. 'C' and Sri. Daya Ram, Sc. 'B', under the work programme of Environmental Hydrology Division.

(S. M. SETH)
DIRECTOR

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Land application of sewage waste raises many environmental issues both as potential resource for fertilizers and a source of pollution. Their contents of trace elements and pathogens represent potential risk for human health. Because of their accumulation in the soil surface, trace elements may induce metabolism problems in plants and animals and consequently contaminate the food chains. The contaminant migration in the soil, although limited, may lead to ground water pollution. The objective of this study is to provide information on utilization of sewage waste for irrigation purposes and their impact on the soil strata and ground water quality.

The characterization of sewage waste indicated that the waste can be used for irrigation purposes. The concentration of various constituents monitored are within normal range and do not constitute a limiting factor for irrigation use. As per the U.S. Salinity Laboratory Classification, the waste water of the BHEL complex falls under the category of medium salinity and low SAR (C2-S1) which is suitable for irrigation purposes. The sewage waste characteristics studied in this report can be considered to have low contaminant levels and can be used for irrigation purposes.

The spatial distribution of total concentration of various constituents in the soil profile showed that most of the constituents are retained within the top 60-75 cm and no substantial migration took place in the soil strata. The quality of ground water in the nearby area is quite normal and does not indicate any appreciable sign of contamination due to land application of sewage waste. However, a management strategy for proper land application of sewage waste should be set up to maintain the sustainability of soils to assimilate pollutants and prevent food chain transfer of hazardour elements.

1.0 INTRODUCTION

1.1 General

Land application of waste water and sewage sludge is an old and common practice which has gone through different development stages with time, knowledge of the processes and treatment technology. The use of waste water and sewage sludge for irrigation purposes raises issues both as potential resources for fertilizers and source of pollution. Their content in organic matter , nitrogen, phosphorous and potassium may improve soil fertility and enhance plant development. However, their content in mineral and organic trace substances and pathogens represents a risk for human health.

The salt content of wasters and sludge and the nutrient losses from waste water application and/or inorganic or organic fertilizers are of primary concern. Management practices to reduce salinity, such as leaching and drainage (Kruse et al., 1990; Oster, 1994) may also remove nutrients and concentrate some toxic elements in the drainage water.

Trace elements may present an environmental concern because of their potential harmful effects on biota (Page and Chang, 1994). They are brought into the soil through water and sludge applications, fertilizers or atmospheric deposition. They may accumulate in the surface layers, be transported to underlying ground water system or be removed through plant uptake. They may then induce metabolism problems in plants and animals and consequently contaminate the food chain.

Among the trace elements, some are essential at low concentrations but toxic at elevated concentrations, e.g., Cu, Cr, Mo, Ni, Se, and Zn (Page and Chang, 1994). Arsenic, cadmium, hexavelant chromium, fluorine, lead, mercury, molybdenum, and selenium are considered of environmental concern because they are taken up by plants in amounts potentially harmful to animals and humans. Boron, cadmium, copper, hexavelant chromium, nickel, zinc, and selenium are of concern because of their phytotoxicity.

These elements may be transferred to animals or humans through different pathways (Ryan and Cheney, 1994) and cause human health effects depending on their concentration.

Trace element accumulation in soils in relation to uptake by plants depends on the chemical forms of elements which can be exchangeable, sorbed, organic bound, carbonate, and sulfide forms (Stover et al., 1976; Silviera and Sommers, 1977; Latterell et al., 1978; Mahler et al., 1980; Sposito et al., 1982). Trace elements uptake by plants can be correlated with some extractable fraction of the element in the soil (Sposito et al., 1982). Their accumulation by plants depends on the soil supplying these elements to plant roots and the characteristics of the plant root system. Soil pH has been shown to have a significant effect on plant uptake of sewage sludge-borne trace elements, much more consistent than other soil variables such as organic content, cation exchange capacity, soil texture, etc. (Page et al., 1987). The toxicity of trace elements to plants is also related to the soil chemical properties and more particularly to the soil pH. With pH > 5.5, no Cu, Cr, Ni, and Zn toxicities have been observed to even very sensitive plants in municipal sludge land application experiments. Trace element toxicities to plants are more common in acid soils. Trace elements can reduce or even prevent plant growth. A methodology for establishing phytotoxicity criteria for some trace elements in agricultural land application of municipal sewage sludge was developed by Chang et al. (1992).

Several long term field experiments have been conducted in different countries on the impacts of land application of reclaimed wastewater and sewage sludge on soils, microorganisms, and plants. Long term environmental impacts from irrigation with reclaimed waste water were reported to be minimal (Chang et al., 1993). Continuous applications of sewage wastes can, however, result in trace element concentration in the surface layer.

Release of trace elements is more likely to happen in acid soils and depending on the chemical form of the element (Nemeth et al., 1993). Other soil components can also react to prevent trace element movement such as clay, organic matter, hydrous iron and manganese oxides, organic acids, amino acids, humic and fulvic acids, etc. (Chaney and Giordano, 1976).

The occurrence of major and trace elements in soils is generally believed to vary spatially (Webster and Nortcliff, 1984), depending on the nature of the soil, parent material and the position of the different soils in the landscape. Knowledge of the spatial structure of the soil chemical elements in the agricultural lands is than important to analyse soil water chemical and leaching characteristics, to evaluate possible crop uptake effects and to predict the ground water quality (Webster and Nortcliff, 1984).

In recent years, an increasing threat to ground water pollution due to human activity has become of great importance. The adverse effects on ground water quality are the results of man's activity at ground surface, unintentionally by agriculture, domestic and industrial effluents, unexpectedly by sub-surface or surface disposal of sewage and industrial wastes.

The problem of collection and disposal of domestic wastewater in urbanized areas is even more acute. Because a large volume of sewage is generated in a small area, the waste cannot be adequately disposed off by conventional septic tanks and cesspools. Therefore, special disposal sites are being used to collect and dispose such wastes in densely populated areas. Shrivastava et al. (1989) studied the pollution status of soil beneath the sewage disposal pond at Jaipur in the state of Rajasthan. In an another report, Olaniya and Saxena (1977) reported serious ground water pollution in the wells due to open refuse dumps at Jaipur. Sewage effluents and sewage disposal ponds contain a variety of organic molecules, hazardous metal ions and biologically active parameters (Hasan and Pande, 1984; Veerannan, 1977). Some of the organic molecules present in sewage disposal ponds and effluents are reported (Tomatis et al., 1972; Kasyap et al., 1977) to be toxic and carcinogenic.

Lund et al. (1976) studied nitrogen and phosphorous leaching due to the sewage drains in the soil and concluded that the subterranean water may suffer contamination by these elements. Starr et al. (1974) studied the simultaneous occurrence of nitrification, denitrification and nitrogen movement in an unsaturated column of soil during the continuous application of ammonium chloride solution. A number of studies have been conducted on the effect of vinasse disposal on the soil and ground water (Casarini et al., 1987; Cunha et al., 1987; Cruz et al., 1991).

The rate of generation of waste water in India during 1981 was estimated to be 74,529 million lit./day, which poses a potential danger of contaminating ground water resource. The problem is likely to compound further with increasing rate of waste water generation which is estimated to be about 1,10,000 million lit./day by the year 2000, when our population would be around one billion. Solid wastes are not behind in adding to ground water contamination problem. In India, the municipal waste (which includes domestic and commercial waste) is produced at an average rate of 0.33 kg/capita/day. Thus the 185 million urban population is expected to produce 22.35 million tons of municipal solid waste every year. Processing of solid waste is rarely carried out and in majority of the cases, the waste is disposed of in low lying areas, where it often comes in contact with surface or ground water thus contaminating it.

1.2 Sources of Ground Water Pollution

The major sources of ground water pollution can broadly be classified in the following categories:

- Urban and domestic wastes
- Industrial wastes
- Agricultural practices
- Induced contaminated water

1.2.1 Urban and domestic wastes

The forms of domestic wastes which can adversely effect the ground water quality are sewage and solid wastes. As in the case of many cities sewage is discharged on agricultural lands without adequate treatment, ground water may get polluted. At many places solid wastes are disposed in open dumps or land fills. Unless disposal sites are selected taking hydrogeological conditions into consideration, precipitation recharge passing through dumps and land fills may leach pollutants resulting in ground water pollution.

Wastes in solid state are produced as a result of various human activities. Wastes produced from residential areas are commonly termed as domestic solid waste. The average composition of the municipal solid waste (which includes domestic and commercial waste) is given in Table 1.

Table 1. Composition of Municipal Solid Waste

Characteristics	Range (%)
Paper	3-6
Plastic	0.5-0.9
Metals	0.5-1.0
Glass	0.3-0.8
Ash and fine earth	30-50
Moisture	20-30
Organic matter	20-30
C	10-15
N	0.5-0.6
P	0.5-0.7
K	0.5-0.7
Calorific value (K cal./kg.)	800-1150

The above waste is commonly collected from premises and taken for processing and disposal. In India, precessing of solid waste is normally not carried out and the material is disposed of in the untreated state in low lying areas where it often comes in contact with surface or ground water thus polluting it.

1.2.2 Industrial wastes

The physical and chemical characteristics of effluents of various industries are widely different with the result that ground water quality susceptible to degradation is related to characteristics of these effluents. Generally the industries discharge their effluents, without adequate treatment, near them. These effluents are either either discharged into pits or passed through unlined channels to nearby depressions where several toxic constituents percolate into the ground water system. Various industries which are known to adversely effect the ground water quality include electroplating, tanneries, dying and textiles, iron and steel, machine and machine tools, manufacture of alloys, chemicals, petroleum, fertilizers and insecticides, paints and pigments, distilleries and breweries, paper and pulp, etc. Various parameters that have potential for ground water pollution and are associated with various industries are given in Table 2.

Industrial waste land fills are the most common source of serious ground water contamination because of their large number and potential for leaching a variety of hazardous substances, that are relatively mobile into the underlying ground water. The potential for contamination from landfill leachate is greatest in areas with shallow ground water table and high rainfall.

1.2.3 Agricultural practices

Ground water pollution due to agricultural sources is mainly derived from fertilizers, irrigation salts, animal wastes and crop waste disposal. Though use of fertilizers in proper quantity is beneficial for the crop yield, its indiscriminate use leads to ground water pollution. High levels of potassium and nitrate in ground water in several parts of the country can be attributed to excessive use of fertilizers. Several insecticides which are applied can also be leached into ground water system. Excess of irrigation water as a result of leaching of salts from soils may also increase several constituents of ground water.

Accumulation of excreta of farm animals and its leaching during monsoon recharge also adversely affect ground water quality.

Table 2. Potential Parameters Associated with Industries

S.No.	Industrial Unit	Potential Parameters
1.	Pulp and paper	Phenols, sulphite, colour, heavy metals, nitrogen, phosphorous, TDS
2.	Petroleum refining	Chloride, colour, copper, cyanide iron, lead, zinc, mercaptans, nitrogen, phosphorous, sulphate, TOC, turbidity, odour
3.	Steel industries	Cyanide, phenols, iron, tin, chromium, zinc
4.	Organic chemical industry	TOC, phosphorous, heavy metals, phenols, cyanide, nitrogen
5.	Inorganic chemicals, alkalies and chlorine industry	Chlorinated benzenoids and poly-nuclear aromatics, phenols, fluoride, phosphorous, cyanide, mercury, copper, lead, titanium, iron, aluminium, boron, arsenic
6.	Plastic materials and synthetic industry	Phosphorous, nitrate, organic nitrogen, chlorinated benzenoids and polynucleararomatics, ammonia, cyanide, zinc, mercaptans
7.	Nitrogen fertilizer industry	Sulphate, org. nitrogencompounds, zinc, calcium, COD, iron, pH, phosphate, sodium
8.	Phosphate fertilizer industry	Acidity, aluminium, arsenic, iron, mercury, nitrogen, sulphate, uranium, fluoride, cadmium
9.	Electroplating	Cyanide, chromium, nickel, copper, cadmium, iron

1.2.4 Induced contaminated water

Movement of contaminated or saline water front in inland aquifers, sea water intrusion due to excessive withdrawals in coastal aquifers and recharge of water contaminated by air pollution may also adversely affect ground water quality.

1.3 Scope of the Study

Almost all major cities of the country are facing pollution problems. Enormous amount of sewage and industrial effluents are being discharged into the nearby land or water course without any treatment leading to ground water pollution. The Bharat Heavy Electricals Limited, Ranipur, Hardwar has constructed a sanitary sewer system to collect the sewage of the township at a central point. The sewage of the area is being collected in large diameter wells away from the township. When the level of sewage becomes sufficiently high, then it is pumped out by electric pumps and is spread over Bengal Engineering Group (BEG) farm for irrigation.

In the present study an attempt has been made to study the impact of sewage waste disposal on the soil strata and quality of ground water of Bahadrabad area in district Hardwar. The proposed study will provide clear picture about the status of pollution due to the disposal of sewage waste on land, which will be useful for taking further action for proper waste management.

2.0 DESCRIPTION OF THE AREA

The area under study is part of indogangetic plains and lies between latitude 29°55′ N to 29°57′ N and longitude 78°2′ E to 78°5′ E in the Hardwar district of Uttar Pradesh, India (Fig. 1). Physiographically the area is generally flat except for the Siwalik hills in the north and north east. The area is devoid of relief features of any prominence except for deep gorges cut by nalas and rivers flowing through the area. The area is bounded by river Yamuna in the west and river Ganga in the east.

The climate of the area as that of the greater part of Indian subcontinent is characterised by moderate type of subtropical monsoonic climate. The average annual rainfall in the area is about 1000 mm, major part of which is received during monsoon period. The major landuse is agriculture and there is no effective forest cover. The soils of the area are loam to silty loam and are free from carbonates.

The most common ground water structure in the area are shallow and deep tubewells. Dugwells are also used as source for drinking water as well as irrigation, but to a lower extent. The ground water body is contained in fine to coarse-grained sands recharged by rainfall. Other sources of ground water replenishment are infiltration from rivers, canals and return flow from irrigation and inflow from the neighbouring areas.

Based on the lithological logs and water table fluctuation data, two types of aquifers have been delineated in the area. The upper one is the shallow unconfined aquifer which generally extends to depths around 25 m. The deeper aquifers are confined to semi-confined in nature and located at depths around 30 to 140 m, below ground level separated by three to four aquifers at average depths of 30 to 55 m, 65 to 90 m, and 120 to 140 m. Water table contours in the area indicate the southward trend of ground water flow in unconfined and confined aquifers.

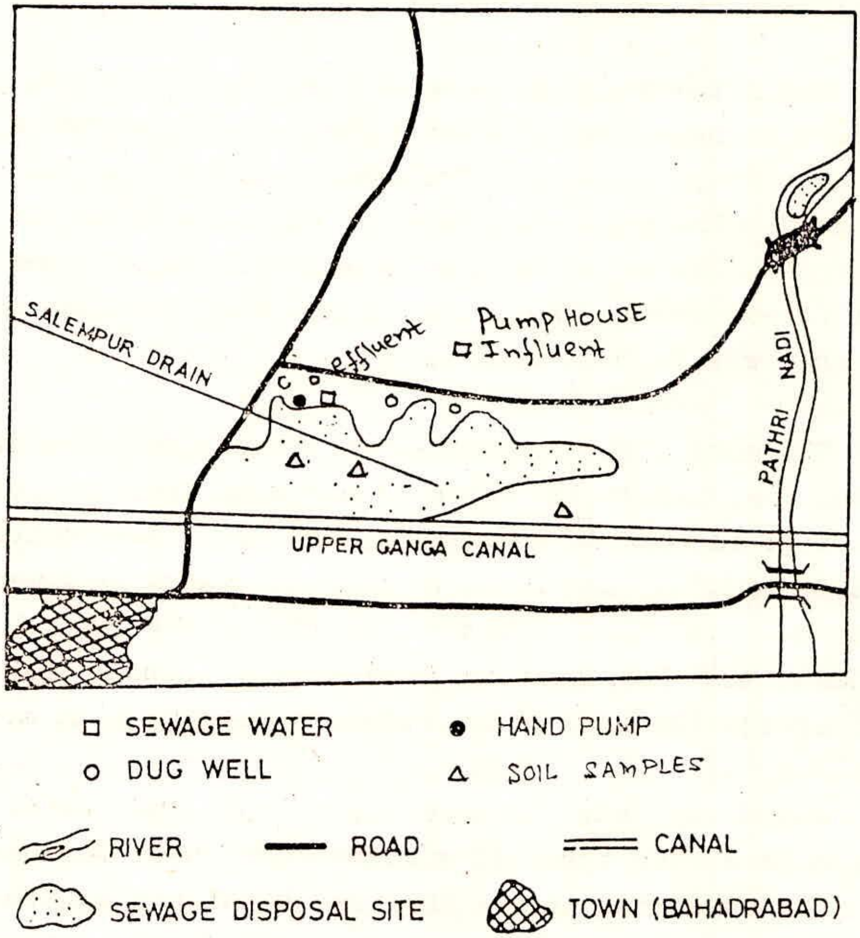

Fig. 1. Study Area and Sampling Locations

3.0 EXPERIMENTAL METHODOLOGY

3.1 Sampling and Preservation

Waste water samples were collected from the influent (pump house used to collect the waste water of the BHEL complex) and effluent the places before it is spread over BEG farm for irrigation) and characterized. Field experiments for the soil sampling were conducted at two locations (A and B) to study the effects of sewage waste application on the soil strata of the waste disposal site. Soil samples were also collected from the off site (control site, C) far away from the disposal site which was never irrigated by the sewage waste and used for comparison of the data.

Soil samples at successive increments of 15 cm upto the depth of 210 cm beneath the sewage waste disposal site and control site were collected during December 1995. The soil samples were air dried, sieved through 2 micron standard ASTM sieve and stored in polyethylene bags for further analysis.

To examine the effect of the percolation of sewage waste on the quality of under ground water, water samples were collected from nearby wells/hand pumps by grab sampling method. Few parameters like pH and conductance were measured in the field at the time of sample collection by using portable kits. For other parameters, samples were collected and preserved by adding an appropriate reagent and brought to the laboratory for detailed chemical analysis of major ions.

3.2 Materials and Methods

All chemicals used in the study were of analytical reagent grade (Merck/BDH). Aqueous solutions were prepared from the respective salts. Double distilled water was used throughout the study. All glasswares and other containers were thoroughly cleaned by soaking in detergent and finally rinsed with double distilled water several times prior to use.

Soil Water Extract (1 : 5) : 100 g of soil sample was mixed with 500 mL of distilled water, shaken vigorously for about one hour and filtered through a 0.45 μm membrane filter. pH and conductance of the soil samples collected from different depths were determined in the suspension form while other constituents like bicarbonates, chloride, sulphate, nitrate, phosphate, sodium, potassium, calcium and magnesium were determined in the filtrate.

Physico-chemical analysis of water and waste water samples were conducted following Standard Methods (APHA, 1985; Jain and Bhatia, 1987). pH and electrical conductance were determined in the field at the time of sample collection using portable meters.

Chloride was estimated by argentometric method in the form of silver chloride. Alkalinity was determined by volumetry using sulfuric acid as titrant and phenolphthalein and methyl orange as indicators. Total hardness and calcium hardness were determined by EDTA titrimetric method while magnesium hardness was calculated by deducting calcium hardness from total hardness. Calcium (as Ca^{++}) was calculated by multiplying calcium hardness with 0.401 while magnesium (as Mg^{++}) by multiplying magnesium hardness with 0.243.

Sodium and potassium were determined by flame-emission method using flame photometer. Nitrogen in the form of nitrate was determined in the ultraviolet range using UV-VIS spectrophotometer. Phosphate was estimated by stannous chloride method in the form of molybdenum blue while sulphate by turbidimetric method in the form of barium sulphate crystals. The summary of analytical methods and equipment used in the study are given in Table 3.

Table 3. Summary of Analytical Methods and Equipment Used

Parameter	Analytical method/Equipment used
pH	pH meter
Conductivity	Conductivity meter
Alkalinity	Volumetry with sulfuric acid
Hardness	Titrimetry with EDTA complexation
Chloride	Titrimetric with mercuric nitrate
Sulphate	Turbidimetric
Phosphate	Ascorbic acid
Nitrate	UV absorption
Sodium	Flame-emission
Potassium	Flame-emission
Calcium	Titrimetry with EDTA complexation
Magnesium	Titrimetry with EDTA complexation
BOD	Dilution and incubation
COD	Dichromate digestion

4.0 RESULTS AND DISCUSSION

Physical, chemical and biological parameters are important in characterizing waste water for design of reuse facilities and in the management of environmental quality. Municipal treatment plants are usually have been designed to remove organic matter and suspended solids, but other waste water constituents may be of concern for different reuse objectives and thus need to be monitored.

The waste water quality of the BHEL complex was studied for various constituents in the sewage waste influent and effluent which is used for irrigation purposes and the results are given in Table 4. The pH of the waste water at the influent and effluent was found towards alkaline side with conductivity value of 580 $\mu S/cm$ in the influent and 569 $\mu S/cm$ in the effluent.

The salts present in the water, besides affecting the growth of the plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. The total concentration of soluble salts in irrigation water can thus be expressed for the purpose of classification of irrigation water as follows:

Zone	TDS (mg/L)	Conductivity ($\mu S/cm$)
Low Salinity Zone	< 200	< 250
Medium Salinity Zone	200-500	250-750
High Salinity Zone	500-1500	750-2250
Very High Salinity Zone	1500-3000	2250-5000

The total dissolved solids in the influent and effluent was found to be 371 and 364 mg/L respectively indicating medium salinity zone. While a high salt concentration in water leads to formation of a saline soil, a high sodium leads to development of an alkali soil. The sodium or alkali hazard in the use of a water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of Sodium

Adsorption Ratio (SAR). If the proportion of sodium is high, the alkali hazard is high; and conversely, if calcium and magnesium predominate, the hazard is less. There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles.

A low SAR (2 to 10) indicate little danger from sodium; medium hazards are between 7 and 18, high hazards between 11 and 26, and very high hazards above that. The lower the ionic strength of the solution, the greater the sodium hazard for a given SAR.

The value of SAR in the sewage waste was found to be less than 1.0 indicating low sodium hazards. Low sodium water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium sodium water presents an appreciable sodium hazard in fine textured soils having good cation exchange capacity, especially under low leaching conditions. Such water may be used on coarse-textural or organic soils with good permeability. High sodium water may produce harmful levels of exchangeable sodium in most soils and will require special soil management like good drainage, high leaching and organic matter additions.

It is clearly evident from Table 4 that all the

Table 4. Physico-chemical Characteristics of Sewage Waste

Parameter	Influent	Effluent
pH	7.6	7.5
Conductivity, μS/cm	580	569
TDS, mg/L	371	364
Alkalinity, mg/L	256	242
Hardness, mg/L	241	237
Chloride, mg/L	18	18
Sulphate, mg/L	34	28
Phosphate, mg/L	0.98	0.70
Nitrate-nitrogen, mg/L	1.90	2.30
Ammonia-nitrogen, mg/L	1.55	1.44
Sodium, mg/L	28	21
Potassium, mg/L	9	7
Calcium, mg/L	81	70
Magnesium, mg/L	21	16
COD, mg/L	44	32
BOD, mg/L	26	20
SAR	0.72	0.59

constituents monitored in the sewage waste are within normal range and do not constitute a limiting factor for irrigation use.

The chemical analysis data of the sewage wastes have also been processed as per the U. S. Salinity Laboratory Classification to further examine the suitability of waste water for irrigation purposes and the results are graphically presented in Fig. 2. It is evident from the figure that the waste water of the BHEL complex falls under the water type C2-S1 (medium salinity and low SAR) which is suitable for irrigation purposes.

4.1 Effect of Sewage Waste Application on Soil Strata

The major constituents in soil samples of the irrigated field were measured to determine the effect of sewage waste water application on chemical composition of soils. The results for the various constituents like pH, conductivity, bicarbonate, chloride, sulphate, phosphate, sodium, potassium, calcium and magnesium were determined in 1 : 5 soil-water extract and are discussed below.

pH is one of the important factor in water quality management. The pH of soil samples collected from different depths (0 to 210 cm) at disposal site A shows a slight increase from 7.3 at depth 15 cm to 7.5 at depth 45-60 cm, after this pH decreases upto a depth of 120 cm to a value of 7.3 and remains almost constant upto a depth of 210 cm. At site B, the pH value shows a slight increase from 7.2 at 15 cm depth to 7.3 at 30-45 cm, than decreases again to 7.2 pH at a depth of 60 cm. A

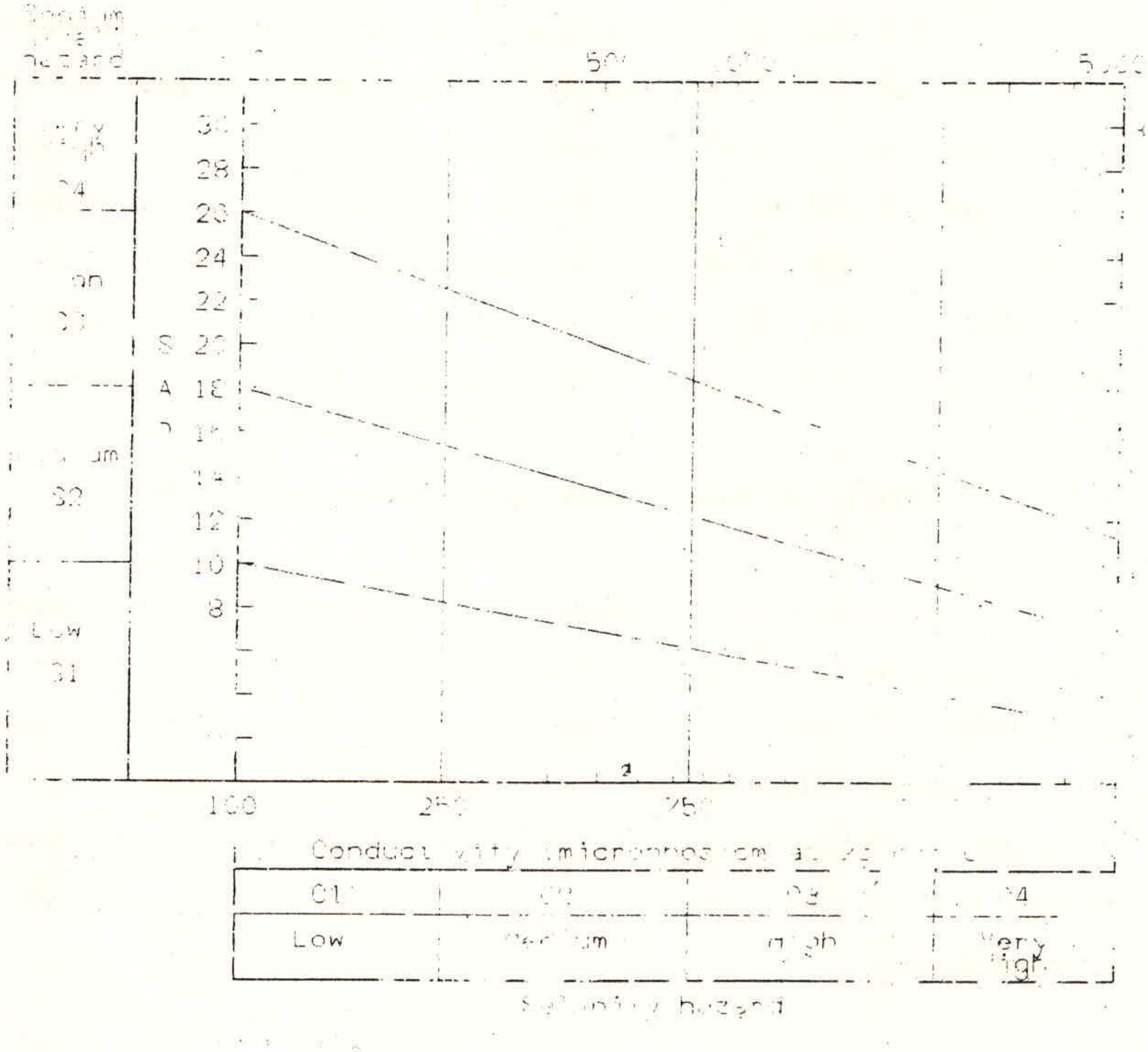

Fig. 2. U.S. Salinity Laboratory Classification of Sewage Waste

comparison of the pH data (Fig. 3) of the disposal site with the data of control site shows enhancement of pH at the disposal site. This enhancement in pH at the disposal site is due to the application of sewage waste, indicating the increase in alkaline nature of the soil at the disposal site. Among the two sampling site (A and B), the increase in pH is more pronounced at site A as compared to site B. It has been reported that a pH value of above 8.8 induces the formation of trihalomethanes in sewage disposal ponds which are toxic in nature. The maximum value of pH at the waste disposal site was found to be 7.5 at a depth of 45-60 cm. This pH is slightly higher as compared to the pH value of 7.1 at the control site.

The conductance value at site A was found to be about 174 μS/cm at the surface, decreases sharply to a value of 55 μS/cm at a depth of 75 cm and than remains almost constant upto a depth of 210 cm (Fig. 4). Almost similar pattern was observed at the waste disposal site B. Compared to initial soil conductivity value, sewage waste application resulted in an small increase in the upper soil surface. This increase, however, did not constitute a polluting load in the short term perspective. A comparison of the conductivity data between the disposal site and control site clearly indicates the percolation of ionic pollutants through the soil strata only upto a depth of about 75 cm. The ionic constituents were retained in the soil and did not migrate further within the soil profile which suggests that contamination of ground water is not likely, at least in the short-term perspective. However, heavy application of sewage sludge with high content of dissolved solids may lead to soil

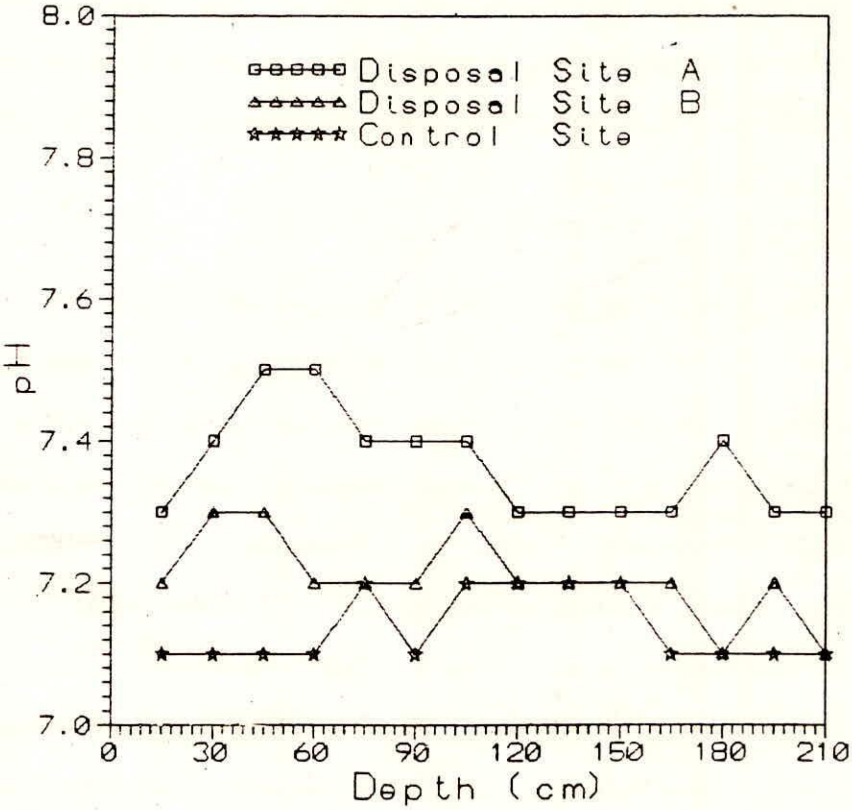

Fig. 3. Variation of Soil pH with Depth

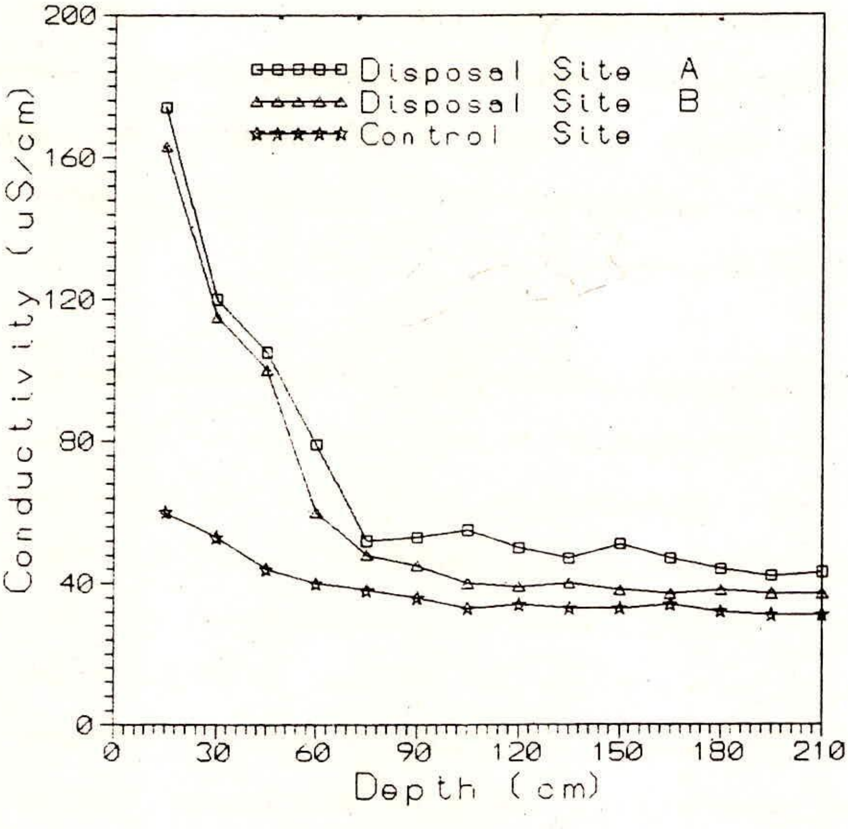

Fig. 4. Variation of Soil Conductivity with Depth

threshold values for some constituents and plants may severely affected (Somashekar, 1984). The higher concentration of sewage waste also changes the characteristics of soil of the irrigated field which in turn may affect the plant growth.

The bicarbonate profiles at the waste disposal site and control site have been shown in Fig. 5. At the upper surface, bicarbonate concentration was found to be 300 $\mu g/g$. It decreases gradually to 280 $\mu g/g$ upto a depth of 45 cm, remains constant upto a depth of 75 cm, and than shows an irregular increasing and decreasing trend. On the other hand, the bicarbonate concentration at the control site was found to vary in a small range of 225-230 $\mu g/g$.

The concentration profile of chloride ions at the waste disposal site alongwith the data from the control site is given in Fig. 6. The concentration of chloride was found to be 92 $\mu g/g$ at the upper surface and decreases to 30 $\mu g/g$ at a depth of about 60 cm at the disposal site. The concentration of chloride ion at the control site vary in the range of 15-30 $\mu g/g$. The increase in the concentration of chloride ion even upto a depth of 210 cm indicates percolation of chloride ions through the soil bed.

The concentration of sulphate ions was found to be 20 $\mu g/g$ at the upper surface (Fig. 7) and depleted to a level of 10 $\mu g/g$ at the depth of 60 cm and then remains almost constant upto a depth of 210 cm with an irregular increase and decrease in between. The natural distribution of sulphate ions in the soil at the control site vary in the range 7-9 $\mu g/g$. The slight

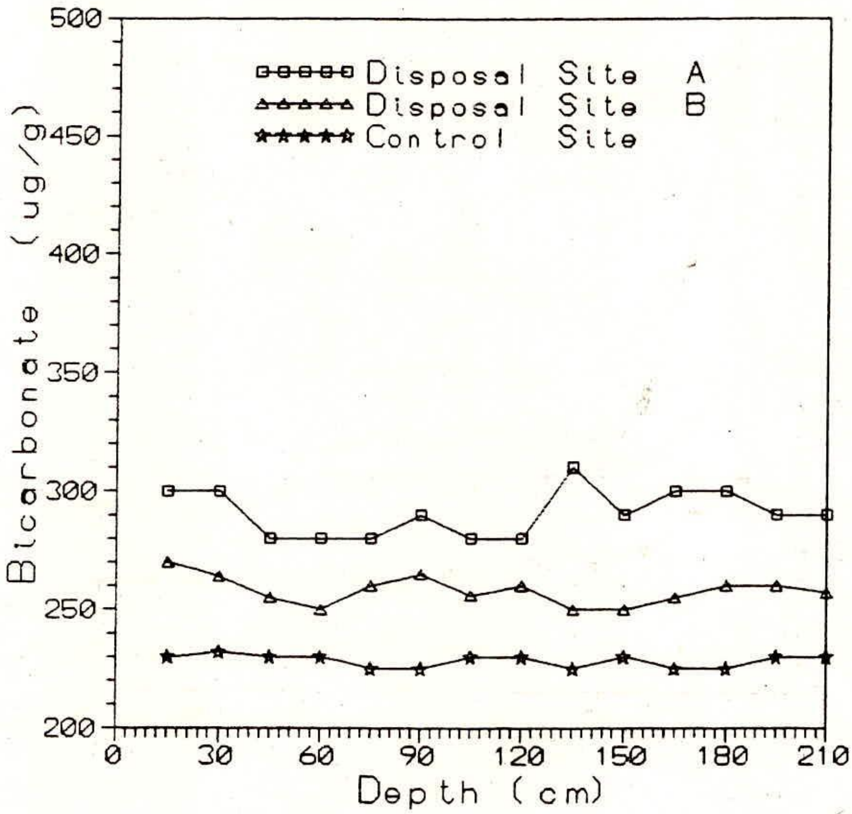

Fig. 5. Variation of Bicarbonate Content in Soil with Depth

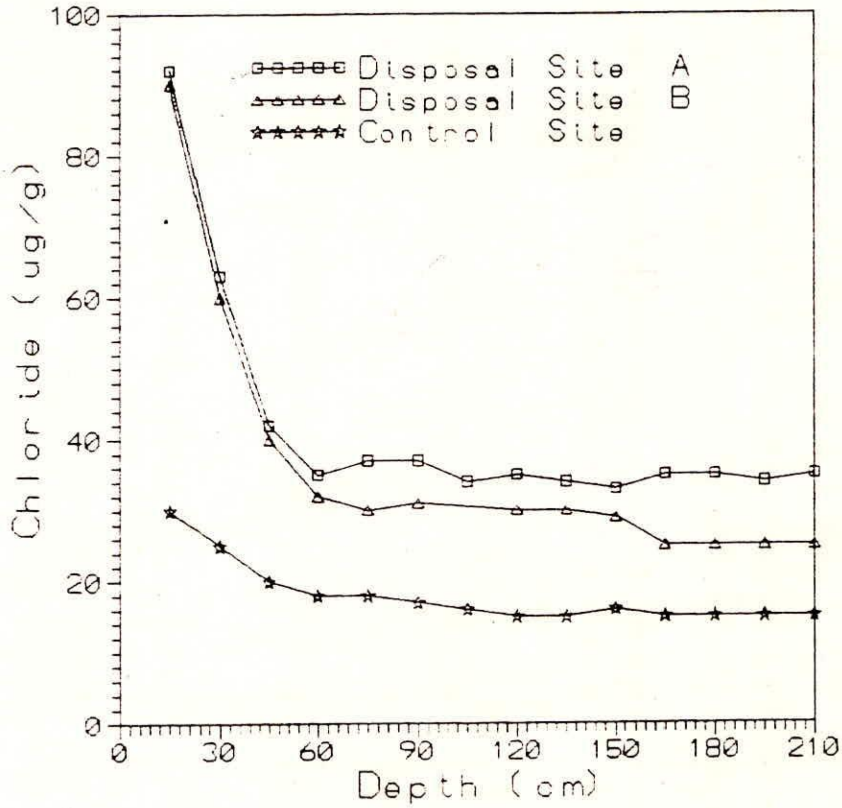

Fig. 6. Variation of Chloride Content in Soil with Depth

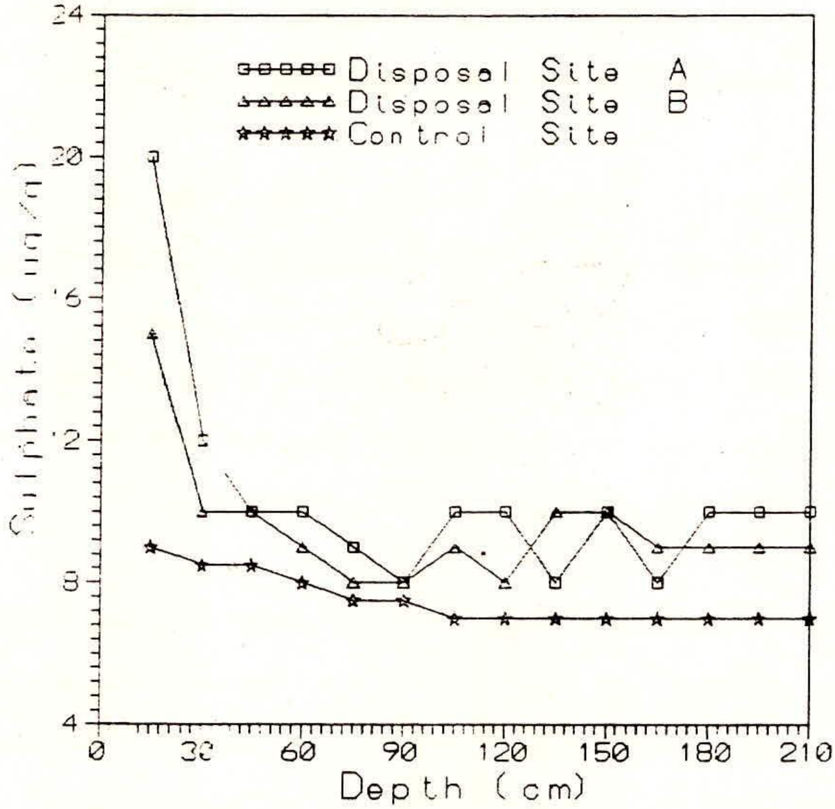

Fig. 7. Variation of Sulphate Content in Soil with Depth

increase at the disposal site may be due to the percolation of these species present in the sewage effluents through the soil bed.

The concentration of phosphate was found to be 0.44 μg/g at the upper surface and decreases upto a value of 0.12 at the depth of 60 cm. (Fig. 8). An almost similar pattern was observed at disposal site B. The natural distribution of phosphate ions in the soil at the control site vary in the range 0.23-0.10 μg/g. There is not much difference in the concentration of phosphate ions at the disposal site and control site.

The sodium content at the waste disposal sites and control site is shown in Fig. 9. At the upper surface, the sodium content was found to be 21 μg/g. It decreases gradually to 6 μg/g at a depth of 75 cm and than remains almost constant upto a depth of 210 cm. The sodium content at the control site was found to vary in the range of 5-6 μg/g.

The potassium content at the waste disposal sites and control site is shown in Fig. 10. At the upper surface, the to 6 μg/g at a depth of 75 cm and than remains almost constant upto a depth of 210 cm. The potassium content at the control site was found to vary in the range of 5-6 μg/g.

The concentration of calcium ions was found 110 and 120 μg/g at the waste disposal site A and B respectively. The calcium content decreases sharply to 65 μg/g at a depth of 120 cm and then decreases slightly to a value of 58 μg/g at a depth of 210

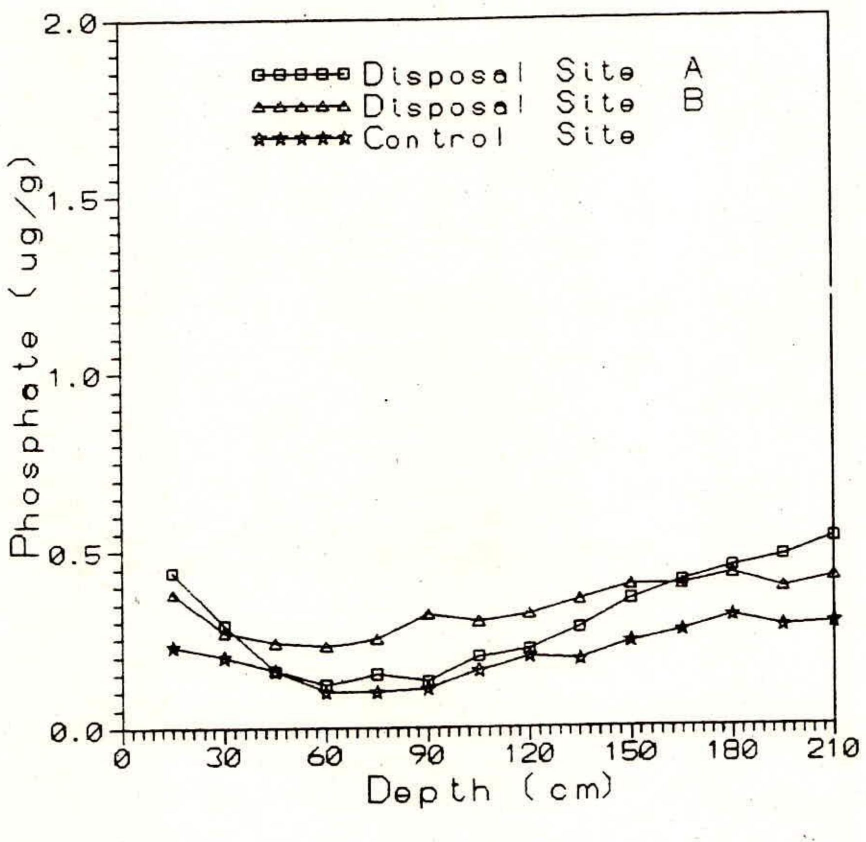

Fig. 8. Variation of Phosphate Content in Soil with Depth

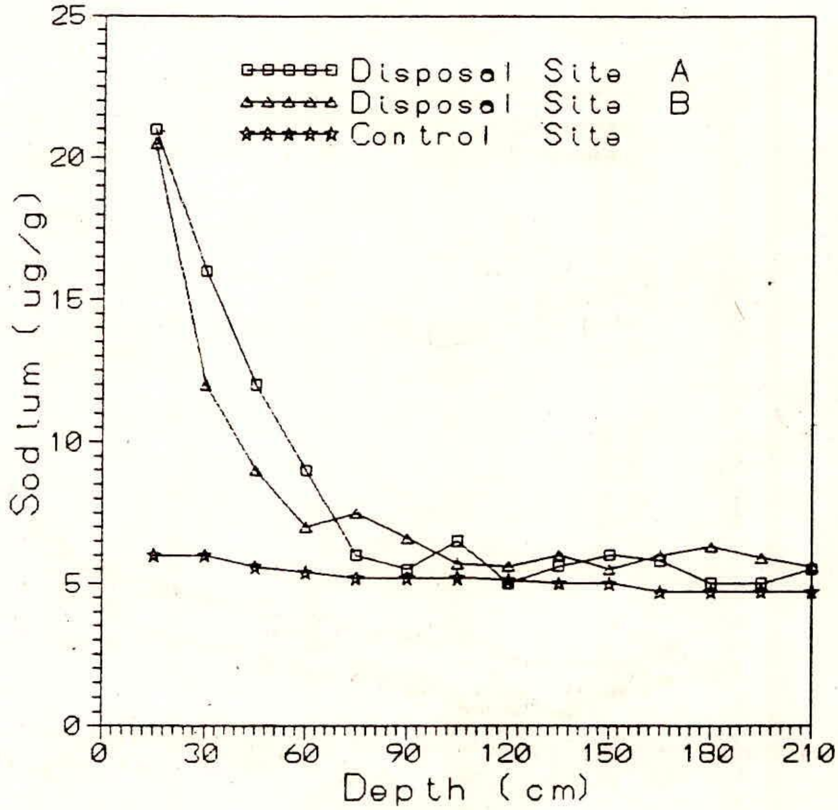

Fig. 9. Variation of Sodium Content in Soil with Depth

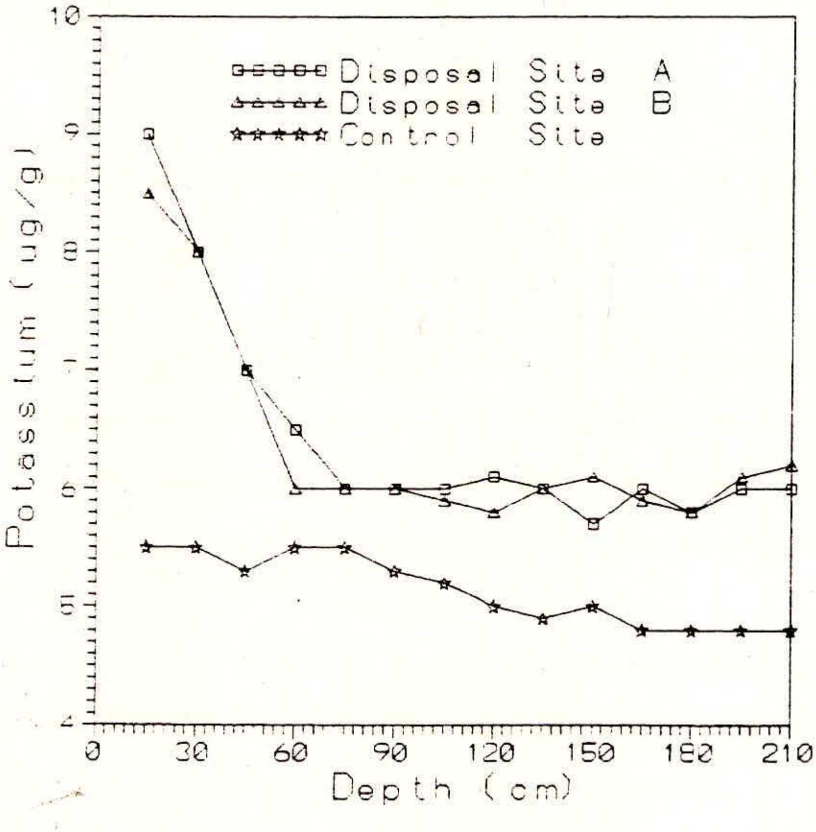

Fig. 10. Variation of Potassium Content in Soil with Depth

cm (Fig. 11). The calcium content at the control site was found to vary in the range of 55-60 μg/g.

The concentration of magnesium ions was found to be 96 and 85 μg/g at the waste disposal site A and B respectively. The magnesium content decreases sharply to 70 and 60 at a depth of 45 cm. A further gradual decrease up to a value of 58 and 42 were observed at site A and B respectively (Fig. 12). The magnesium content at the control site was found to vary in the range of 25-30 μg/g.

4.2 Effect of Sewage Waste Application on Ground Water Quality

In order to study the effect of sewage waste water application on the quality of ground water, water samples were collected from the nearby wells and hand pumps (Fig. 1) and characterized for various constituents.

The chemical characteristics of the ground water samples are given in Table 5. The ground water of the region was characterized by a slightly basic pH and a slightly low salinity and sodium adsorption ratio (SAR).

A pH range of 6.5 to 8.5 is normally acceptable as per guidelines suggested by WHO (1984) and BIS (1983). The pH value in the nearby area of the waste disposal site lies in the range 7.1 to 7.6 (Table 5, which is well within the limits prescribed by WHO and BIS for various uses of water including drinking water

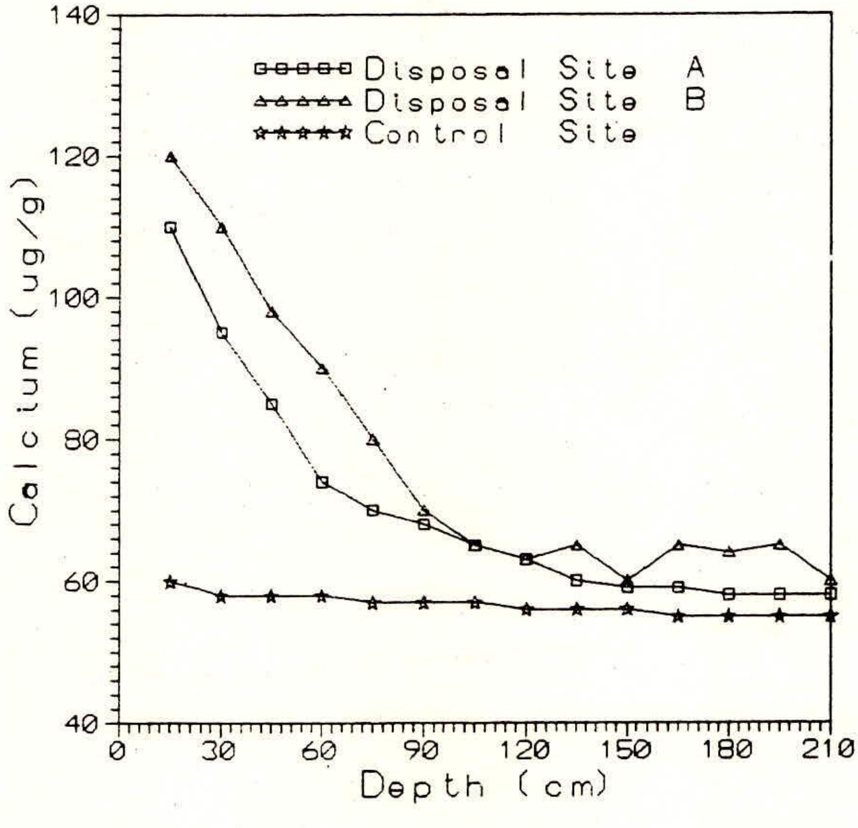

Fig. 11. Variation of Calcium Content in Soil with Depth

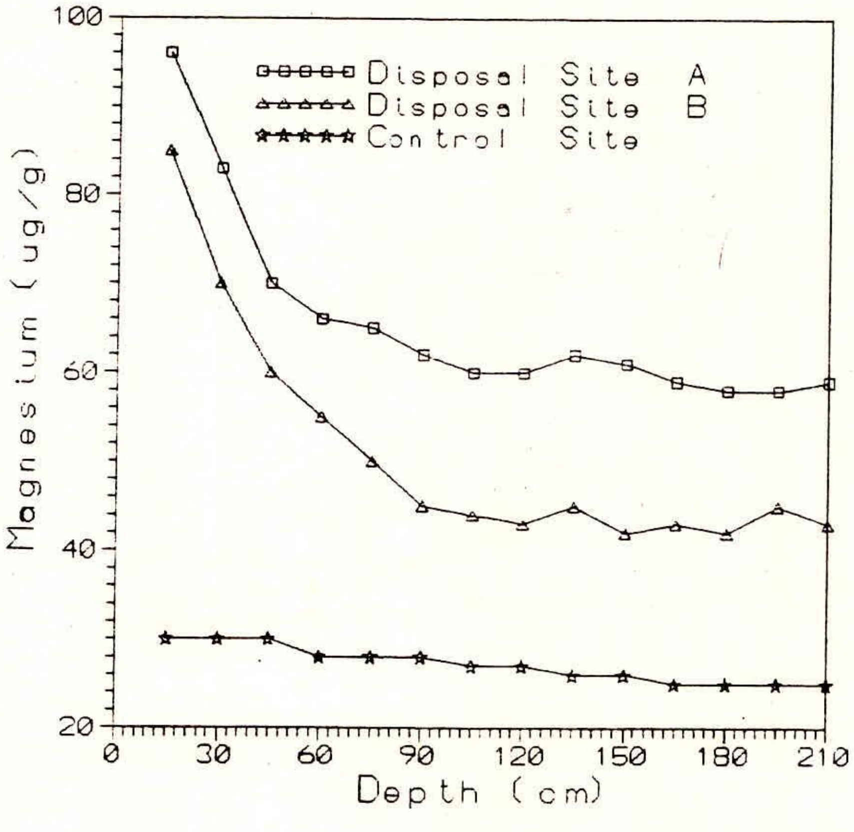

Fig. 12. Variation of Magnesium Content in Soil with Depth

Table 5. Physico-chemical Characteristics of Ground Water

Parameter	A	B	C	D	E
pH	7.6	7.6	7.1	7.1	7.1
Conductivity, μS/cm	434	605	430	405	556
TDS, mg/L	277	387	275	259	355
Alkalinity, mg/L	206	254	205	208	260
Hardness, mg/L	211	292	224	216	280
Chloride, mg/L	22	34	24	20	28
Sulphate, mg/L	16	16	14	8	9
Phosphate, mg/L	0.14	0.32	0.08	0.09	0.04
Nitrate, mg/L	8.4	5.6	10	6.6	9.0
Sodium, mg/L	28	36	21	30	26
Potassium, mg/L	12	11	7	6	8
Calcium, mg/L	55	64	42	53	88
Magnesium, mg/L	18	32	29	20	15
SAR	0.84	0.92	0.61	0.89	0.77

A : Hand pump at the disposal site
B : Open well near the disposal site
C : Hand pump near the disposal sits
D : Hand pump near the disposal site
E : Hand pump near the disposal site

and other domestic supplies.

The electrical conductivity value is used as a criterion for expressing the total concentration of soluble salts in water. The conductivity value in the vicinity of the disposal site varies from 405 to 605 μS/cm during December 1995, which is close to the conductivity value of the ground water samples of district Hardwar (Jain et al., 1995).

Total dissolved solids (TDS) indicate the general nature of water quality or salinity. Water containing more than 500 mg/L of TDS in not considered desirable for drinking water supplies (BIS, 1983). The TDS value in the ground water of the nearby area varies from 259 to 387 mg/L.

The alkalinity values in the area varies from 205 to 260 mg/L during December 1995. This value is quite normal with respect to alkalinity value in ground water of district Hardwar.

The sodium and potassium contents are also within the normal range and varies from 21 to 36 mg/L and 6 to 12 mg/L respectively. Sodium concentration more than 50 mg/L makes the water unsuitable for domestic use.

Calcium, magnesium and total hardness in the water are inter-related and hence combined in the description. The upper limits for calcium and magnesium for drinking water and domestic use are 75 and 30 mg/L respectively (BIS, 1983). In ground water of the area under study, calcium and magnesium ranges from 42 to

88 mg/L and 15 to 32 mg/L respectively during December (Table 5).

Calcium and magnesium along with their carbonates, sulphates and chlorides makes the water hard, both temporarily and permanent. A limit of 300 mg/L has been recommended for potable waters (BIS, 1983). The ground water in the area contains these ions in quite normal concentrations. The total hardness as $CaCO_3$ ranges from 211 to 292 mg/L during December 1995. From the hardness point of view, the ground water is suitable for drinking and other domestic applications.

The chloride content in the study area is well within the limits prescribed for drinking water supplies. A limit of 250 mg/L chloride has been recommended for drinking water supplies (BIS, 1983; WHO, 1984). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. A concentration of more than 250 mg/L of chloride makes the water unsuitable for a number of domestic applications.

The sulphate content in the ground water of the study area lies well below the permissible value for domestic applications. A limit of 150 mg/L sulphate has been suggested for drinking water supplies (BIS, 1983). Sulphate content more than 150 mg/L is objectionable for many domestic purposes. Water containing more than 500 ppm sulphate tastes bitter and beyond 1000 ppm, it has purgative effect.

The chemical analysis data of the ground water samples have been processed as per Stiff and Piper trilinear diagram to study the quality of ground water of the region.

The Stiff classification (Stiff, 1951) is used to classify the type of water based on dominant cations and anions. As per Stiff classification, the ground water of the area falls under calcium bicarbonate type.

Piper classification (1953) is used to express similarity and dissimilarity in the chemistry of different water samples based on the dominant cations and anions. This diagram is an effective tool in segregating analysis data with respect to sources of the dissolved constituents in ground water, modifications in the character of a water as it passes through an area, and related geochemical problems. For the trilinear diagram, ground water is treated substantially as though it contained three cation constituents (Mg, Na+K and Ca) and three anion constituents (Cl, SO_4 and HCO_3). The diagram presents graphically a group of analysis on the same plot.

The chemical analysis data of the ground water samples have been plotted on trilinear diagram (Fig. 13). The cation plots in the diagram reveals that, ground water samples of the study area falls in calcium and no dominant type. The anion plots in the diagram indicate that the samples fall in bicarbonate type. These two trilinear plots indicate that the ground water of the study area are of calcium, bicarbonate and no dominant types.

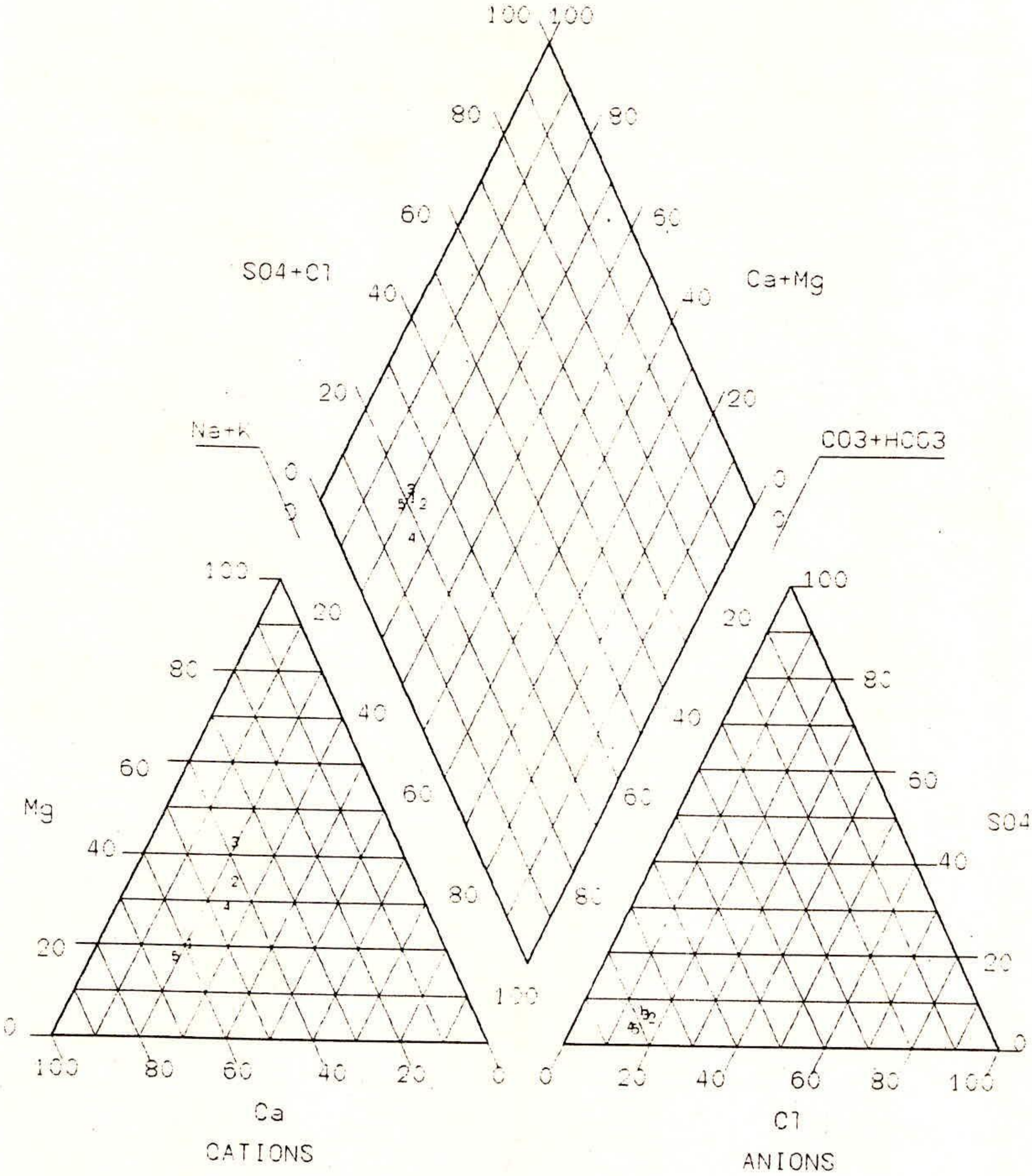

Fig. 13. Piper Trilinear Diagram Showing Chemical Character of Ground Water

The diagram combines three different areas for plotting, two triangle areas (cation and anion) and an intervening diamond shaped area (combined field). Using this diagram waters can be classified into four different hydrochemical facies. All the samples of the study area falls in Ca - Mg - HCO_3 facies.

5.0 CONCLUSION

The application of sewage waste to the soil generates a great number of physical, chemical and biological reactions that need to be simultaneously analysed in order to determine the localization of the products of these reactions. The problem of sewage disposal is critical in the consideration of environmental pollution, needing much more research into the understanding of the dynamic aspects of soil-water-atmosphere interactions.

Waste water and sewage are important supplement in agriculture. The use of sewage waste water for irrigation purpose is also a better way to dispose it off rather than disposing it in natural streams. The study on sewage waste in this report can be considered to have low contaminant levels and can be used for agricultural use. Land application of sewage waste water can be considered as an additional treatment step for waste water pollutants while organic matter, N, and P brought into the soil will improve its fertility. The application of waste water resulted in an small increase in the upper surface only.

A management strategy for proper land application of sewage waste water should be set up to maintain the sustainability of soils to assimilate and prevent food chain transfer of hazardous elements. The results acquired in the present study are of interest but research efforts have to be made on long term environmental impact studies of land application of sewage waste water.

REFERENCES

1. APHA (1985), Standard Methods for the Examination of Water and Waste Water, American Public Health Association, New York.

2. Casarini, D. C. P., Cunha, R. C. A. and Maset Filho, B. (1987), Effects of irrigation with vinasse and the dynamics of its constituents in the soil: II - Microbiological aspects, Wat. Sci. Tech., Vol. 19(8), 167-176.

3. Chaney, R. L. and Giordano, P. M. (1976), Microelements as related to plant deficiencies and toxicities, pp. 234-279. In: Elliot, L. F. and Stevenson, F. J. (eds.), Soils for management of organic wastes and waste waters, Soil Sci. Soc. Am., Madison, Wisc.

4. Chang, A. C., Granato, T. C. and Page, A. L. (1992), A methodology for establishing phytotoxicity criteria for chromium, copper, nickel, and zinc in agricultural land application of municipal sewage sludge, J. Environ. Qual., 21, 521-536.

5. Chang, A. C., Page, A. L. and Asano, T. (1993), Developing human health-related chemical guidelines for reclaimed waste water and sewage sludge application in agriculture, Report submitted to Community Water Supply and Sanitation Unit, Division of Environmental Health, World Health Organisation, Genewa, Switzerland.

6. Cruz, R. L., Righetto, A. M. and Nogueira, M. A. (1991), Experimental investigation of soil and ground water impacts caused by vinasse disposal, Wat. Sci. Tech., Vol. 24(11), 77-85.

7. Cunha, A. R. C., Costa, A. C. S., Maset Filho, B. and Casarini, D. C. P. (1987), Effects of irrigation with vinasse and the dynamics of its constituents in the soil: I - Physical and chemical aspects, Wat. Sci. Tech., Vol. 19(8), 155-165.

8. Hasan, M. Z. and Pande, S. P. (1984), Indian J. Environ. Hlth., 26, 1.

9. Jain, C. K. and Bhatia, K. K. S. (1987), Physico-chemical Analysis of Water and Wastewater, User's Manual UM-26, National Institute of Hydrology, Roorkee, 1987-88.

10. Kasyap, S. K. (1977), Int. J. of Cancer, 19, 725.

11. Kruse, G. L., Willardson, L. and Ayars, J. (1990), On-farm irrigation and drainage practices, p. 349-371, In: Tanji, K. K. (ed.), Agricultural Salinity Assessment and Management, American Society of Civil Engineers (ASCE), New York, N.Y.

12. Latterell, J. J., Dowdy, R. H. and Larson, W. E. (1978), Correlation of extractable metals and metal uptake of snap beans grown on soil amended with sewage sludge, J. Environ. Qual., 7, 435-440.

13. Lund, L. J., Page, A. L. and Nelson, C. O. (1976), Nitrogen and phosphorous levels in soil beneath sewage disposal ponds, J. Environ. Qual., 5(1), 26-30.

14. Mahler, R. J., Bingham, F. T., Sposito, G. and Page, A. L. (1980), Cadmium enriched sewage sludge application to acid and calcarious soils: relation between treatment, Cd in saturation extract and Cd treatment, J. Environ. Qual., 9, 359-364.

15. Nemeth, T., Molnar, E., Csillag, J., Butjas, K., Lukacs, A., Partay, G., Feher, J. and Genuchten, M. Th van (1993), Mobility of some heavy metals in soil-plant systems studied on soil monoliths, Wat. Sci. Tech., 28, 389-398.

16. Olaniya, M. S. and Saxena, K. L. (1977), Indian J. Environ. Hlth., 19, 176.

17. Oster, J. D. (1994), Irrigation with poor quality water, Review article, Agriculture Water Management, 25, 271-297.

18. Page, A.L., Logan, T. J. and Ryan, J. A. (eds.) (1987), Land application of sludge-food chain implications, Lewis Publishers, Chelsea, MI.

19. Page, A.L. and Change, A.C. (1994), Trace element of environmental concern in terrestrial ecosystems: An overview, pp. 568-585, In: Transactions of the 15th World Congress of Soil Science, Vol, 3a, Commission II: Symposia, Acapulco, Mexico, 10-16 July, 1994.

20. Ryan, J.A. and Channey R.L. (1994), Development of limits for land application of municipal sewage sludge: Risk Assessment pp. 534-553, In: Transactions of 15th World Congress of Soil Science, Vol. 3a Commission II: Symposia, Acapulco, Mexico, 10-16 July, 1994.

21. Shrivastava, V. S., Rai, A. K. and Mehrotra, R. C. (1989), Pollution status of soils beneath sewage disposal pond, Indian J. Environ. Hlth., 31(4), 314-320.

22. Silviera, D.J. and Sommers, L.E. (1977), Extractability of Copper, Zinc, Cadmium and Lead in soils incubated with sewage sludge, J. Environ. Qual., 6, 47-52.

23. Somashekar, R. K., Gowda, M. T. G., Shettigar, S. L. N. and Srinath, K. P. (1984), Indian J. Environ. Hlth., 26, 136.

24. Sposito, G., Lund, L.J. and Change, A.C. (1982), Trace metal chemistry in arid- zone field soils amended with sewage sludge: 1. Fractionation of Ni, Cu, Zn, Cd, and Pb in solid phase, Soil Sci. Soc. Am. J. 46, 260-264.

25. Starr, J. L., Broadbent, F. E. and Nielson, D. R. (1974), Nitrogen transformations during continuous leaching, Soil Sci. Soc. Am. Proc., 38, 283-289.

26. Stover, R. C., Sommers, L.E. and Silviera, D. J. (1976), Evaluation of metals in wastewater sludge, JWPCF, 48, 2165-2175.

27. Tomatis, L., Turnsov, V., Day, N. and Charles, R. T. (1972), Int. J. of Cancer, 16, 489.

28. Veerannan, K. M. (1977), Indian J. Environ. Hlth., 19, 176.

29. Webster, R. and Nortcliff, S. (1984), Improved estimation of micro nutrients in hectare plots of Sonning Series, J. of Soil Science, 35, 667-672.

DIRECTOR S M SETH

DIVISIONAL HEAD K K S BHATIA

STUDY GROUP

C K JAIN, Sc. 'C'
DAYA RAM, Sc. 'B'

LABORATORY STAFF

BABITA SHARMA, JRA
RAKESH GOYAL, Tech. Gr. II
T R SAPRA, Tech. Gr. II
DAYA NAND, Tech. Gr. III
TEJ PAL SINGH, Attandent