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Impact of Sewage Farming in Nagpur Rural Areas

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ABSTRACT: With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. Scientists around the globe are working on new ways of conserving water. It is an opportune time, to refocus on one of the ways to recycle water—through the reuse of urban wastewater, for irrigation and other purposes. This could release clean water for use in other sectors that need fresh water and provide water to sectors that can utilize wastewater e.g., for irrigation and other ecosystem services. In general, wastewater comprises liquid wastes generated by households, industry, commercial sources, as a result of daily usage, production, and consumption activities. Sewage farms use sewage for irrigation and fertilizing agricultural land. The practice is common in warm, arid climates where irrigation is valuable while sources of fresh water are scarce. Suspended solids may be converted to humus by microbes and bacteria in order to supply nitrogen, phosphorus and other plant nutrients for crop growth. Sewage farming allows use for irrigation of water which might otherwise be wasted. Some of the nutrients and organic solids in wastewater can be usefully incorporated into soil and agricultural products rather than fouling natural aquatic environments. Pumping to the point of application may be the only requirement if the village is not at a higher elevation than the sewage farm. In this paper, analysis Nagpur Rural Areas for Studies impact of sewage of farming.

KEYWORDS: Groundwater, Sewage Farming, Agriculture, Irrigation, Nagpur City

I. INTRODUCTION

Disposal of municipal sewage water is one of the most serious problems in many countries due to rapid growth rate of population and industrialization. Today, the total sewage generation per annum from 200 major cities of India is about 2600 million m³ (Som et al, 1994). Sewage disposal in our country is occurring in haphazard manner, which causes serious land and water pollution. Almost all of our major rivers are now threatened with such problems as the uncontrolled discharge and inflush of various kinds of domestic sewage waste water in different water bodies are the main cause of water pollution. Hence, disposal of municipal sewage and other sanitary and domestic waste has become one of the principal problems.

Concurrently, agricultural irrigation with sewage waste water is becoming a common and ever increasing practice in arid and semi-arid areas. In our country, 32 municipal committees are utilizing about 82000 m³ of partially treated sewage water per day for irrigating around 17400 hectares of agricultural land (Yawalkar et al, 1981) and it has been calculated that sewage available from big cities in India could annually contribute 33000 tonnes of Nitrogen, 7000 tones of Phosphorus and 20,000 tonnes of Potassium (Anon, 1982). Sewage sludge from urban areas can provide for 1.2, 1.0 and 0.8 millions tonnes of nitrogen, phosphorus and potassium respectively. An estimated 162.7 million litres of untreated sewage produced in Haryana per day could be utilized directly without pre-treatment for irrigating 3345 hectares of vegetable crops, 5017 hectares of fodder crops or 4459 hectares of cereal crops (Baddesha et al, 1986).

Sewage waste water not only contains the useful but also contains many harmful materials because it is the mixture of domestic, municipal and industrial wastes which add detergents, various salts, DDT and other pesticides used for domestic, sanitation and public health purpose and also heavy metals (Maiti et al, 1992).

One of the main problems today, being faced by the metropolitan cities is disposal of large volumes of liquid and solid waste due to urban and industrial activities and also there is a great need to conserve and reuse water resources. So, in

most of the Asian countries, due to the limited facilities for the treatment of sewage water, the raw sewage is used as such in the agricultural land. It is one of the oldest forms of water reclamation as well as land application of sewage waste water is most viable and ecologically feasible of all the methods of sewage disposal because in developing countries there has not been much emphasis on the installation of sewage treatment plants.

Reuse of sewage waste water is a potential source of supplemental irrigation to meet increasing demand for crop water requirements in many arid and semi- arid countries of the world where fresh water supplies are inadequate for sustained irrigated agriculture. The amount of sewage waste water is expected to increase in future with the increase in population, urbanization and industrialization. Farmers around cities and towns use sewage waste water for irrigation of vegetable and fodder crops on a large scale but the industrial effluents are generally left as such to pollute the surroundings and river water.

Application of sewage waste water to agricultural land is being viewed with concern and it has become a challenge to dispose it off in a way that is environmentally acceptable, economically feasible and is least hazardous to human health. Recycling of wastewater for irrigational purpose may not only solve the disposal problem but also serve as an additional source of liquid fertilizer providing all the macro and micronutrients needed for the growing crops (Soon et al, 1978).

Recycling of sewage waste water in agricultural irrigation is becoming a common and ever increasing practice because of two reasons. Firstly, sewage waste water represents an extra source of water available to the rural sector for irrigation. This is very important in areas suffering from water shortage where the increasing water demand of the urban sector is filled by reducing the water supply to rural sector. Sewage waste water is quantitatively reliable as a source of water for irrigation, since its flow depends neither on rains nor on the general water balance of the region. Secondly, it adds a significant polishing treatment to the effluents through several processes, viz. breakdown of xenobiotic compounds, evaporation of volatile compounds, die-off of pathogens, recycling of part of the nutrients through the crops and biological degradation of the remaining organic matter (Juanico, 1996).

Although land disposal of sewage effluents is not new but they attracted our attention only recently. There are many sites where relatively large volumes of sewage effluents are used to irrigate agricultural lands. Previously, the main objective behind application of municipal and industrial effluents to the land was considered simply as disposal of waste. But now-a-days, it is envisaged to be a valuable resource for any nation since it contains enormous quantity of nutrients. So, it is necessary to use land treatment as one of the available alternatives for the waste management system. Currently, land as a waste management system is getting an edge over the surface water discharge method because discharging of any pollutant over land has less environmental impact than discharging them in any water body.

The main aims of discharging the sewage waste water on the land are :

- Recycling of potential sewage pollutants through the production of agriculture
- Reclamation of waste water
- Minimization of environmental pollution
- To reduce or eliminate the problems related to sewage handling, storage and disposal • To exploit sewage effluent as substitute for fresh water for irrigation due to limited water sources
- To avoid costly treatment of wastewater for discharge
- To avoid the problem of high cost of fertilizer
- To preserve the quality of surface water (use of land for waste disposal over water based system)

Land treatment cannot guarantee complete safety against hazards from sewage disposal due to manifold problems associated with it which arise in the course of management. Evaluation of the success of any such operation ultimately rests on a critical appraisal of the practice. Though several application systems are in operation since the beginning of the century in various countries, but the advocates of land waste water application systems have not paid proper attention to the problems associated with the contamination of ground water in the region of discharge

In India, sewage utilization as a source of irrigation and nutrient supply started as early as in 1896, when one of the first sewage farm was established. Since then, sewage farming is practiced involving the use of raw sewage, diluted sewage and sometimes partially treated sewage. It was reported that the number of sewage farms in our country comes around

132, covering about 12000 hectares of land and utilizing about 223 million gallons per day of sewage. (Moorthy et al, 1973). A critical perusal of the figures indicates a trend of increasing fascination towards domestic sewage recycling through land application. Nutrient supplying potential of sewage is directly related to its consumption, which in turn depends on the extent of industrialization and urbanization of the area from where sewage is generated. In general, the sewage generated in India contains more than 90% water. The solid portion contains 40-50% organics, 30-40% inert materials, 10-15% bio-resistant organics and 5-8% miscellaneous substances on oven dry weight basis (Olinya, 1998). It contains good amount of nitrogen, phosphorus, potassium and micronutrients like iron, zinc, copper and manganese. However, sewage also contains hazardous heavy metals like lead, cadmium, chromium, cobalt and nickel (Soni et al, 1994).

Sewage waste water application to soil plant system can provide an efficient treatment only under very strict condition of control of both the quality and quantity of disposed effluent as well as land management devices. The benefit of application of municipal sewage and sludge on land increased the crop production (Azad, 1992 and Mahida, 1981). The potential benefits of this practice include reduced cost of treatment and energy inputs, reduction or elimination of problems related to sludge handling, storage and disposal as well as increase in the amount of organic matter in soils.

Despite these advantages we cannot neglect the manifold problems associated with land application of sewage waste water which is contaminated with excessive amount of nitrates, chlorides, phosphates and other hazardous chemicals including heavy metals like Pb, Cd, Zn, Co, Cr and Ni etc. (Adhikari et al, 1998, Barti and Jacob, 1998, Brar and Arora, 1997, Narwal et al, 1996, Adhikari et al, 1994, and Hundal and Sandhu, 1990) which may ultimately cause severe soil pollution.

In most of the countries, the composition of untreated sewage is generally suitable with regard to both pollution and irrigation water quality for its use in agriculture. Tapping this resource can save fertilizer and irrigation costs tremendously and can help to boost agricultural production in arid and semiarid countries. However, at present only 10 to 40 percent of sewage water is being used for growing vegetables and that too only in the vicinity of big towns.

Use of sewage for raising crops, commonly known as sewage farming, seems to be favored by municipalities. In many places municipal committees are even earning huge sums through auction of sewage. However, for optimum growth plants should be supplied with water and nutrients as per their requirement which varies with their physiological growth stages. Most of the plants require continuous application of nutrients especially near the maturity stage. As sewage contains large quantities of nutrients, its continuous application increases soil fertility.

Water is considered as a limited and vulnerable resource, essential for life. Currently agricultural land has become a disposal site for waste water. Waste water is used as a source of irrigation water since it serves as a source of plant nutrients. It allows farmers to reduce the use of chemical fertilizers. In this situation, waste water components can be used as an option to supply nutrients for crop growth productively. The main problem with waste water utilization for irrigation in agriculture, apart from the possibility of containing hazardous constituents, such as trace elements and organic compounds, has the risk of polluting ground water. Sewage must be treated to adapt it to agricultural uses, but treatment is also essential for safe environmental disposal, therefore, the relevant costs of waste water for agricultural reuse are just the additional costs needed for adaptation to agriculture.

In agricultural practices, irrigation water quality is believed to affect the soil characteristics, crops production and management of water. For instance, the application of saline/sodic water results in the reduction of crop yield and deterioration of the physical/chemical properties of soil (Singh, 2011). Therefore, it is of concern to the farmers if an irrigation is used, which may contain constituents capable of creating adverse effects on the soil and on agricultural produce. Concern for public health has been the most important constraint in the use of waste water. Waste water carries a wide spectrum of pathogenic organisms posing a risk to agricultural workers, crop handlers and consumers (Blumenthal et al. 2001). High levels of nitrogen in waste water may result in nitrate pollution of groundwater sources used for drinking, which could lead to adverse health effects.

The growth of towns, cities, and development of industries by 19th century leads to problem of disposal of sewage, which encouraged the use of sewage wastewater in irrigation. The practice of use of domestic sewage in farming is becoming prevalent as the demand of water is increasing. In Due to fast industrial development and the growth of population, the availability of water decreases day to day. In this increase in the population has led to increased demand

of water and the increased generation of waste- water. The high-quality water is preserved and the lower quality is used for agricultural purposes. Irrigation with sewage became a prevalent practice in arid and semiarid regions, where it was readily available and economic to freshwater. In the final aim of sewage management is the protection of the environment which the ultimate goal of wastewater management is the protection of the environment in a manner corresponding with public health and socioeconomic concerns.

Sewage farming started early in the 16th century in Germany (1531) and steadily extended to other parts in the world as it started in USA, France, India, Australia, Mexico, and Egypt respectively in 1871, 1872, 1877, 1893, 1904 and 1930. In Egypt, the first installed sewage farm was installed in 1930 at El-Gabal Al-Asfer near Cairo and sewage farms gradually disseminated in other regions at Abu-Rawash, Luxor, El-Saff, Ismailia and Alexandria. Nowadays many developing countries, e.g., Bahrain, Jordan, Kuwait, Qatar, Saudi Arabia, Peru, South Africa, Tunis, and UAE are using treated sewage effluent in farming. On the other hand, some countries like Chili, Iran, India, Afghanistan, Algeria, Morocco, Syria and Lebanon are still using raw sewage effluent in farming. At the time being, sewage farming represents one of the substantial natural water resources that should be well managed, rather than discarded as irrigation with adequately treated sewage effluent might not seem to present any significant or unacceptable risks. Nevertheless, irrigation with sewage effluent must be applied with proper precautions to protect human health and the environment.

II. LITERATURE REVIEW

Sewage water has long been a problem for developed as well as developing countries. With the growing population, urbanization and industrialization, the quantity of sewer water is increasing day by day. It is estimated that at the end of 2000 A.D. approximately 18000 million litres of sewage will be released worldwide per day (FAI, 2000).

Municipal sewage being very much rich in nutrients can be used as a source of irrigation water. This will also minimize the water pollution problems resulting due to the direct discharge of sewage in water bodies. Sewage has been used in agriculture from the very beginning of civilization. But in earlier days, as there were not many industries and automobiles, contamination of sewage was limited.

As the civilization progressed, industries developed and with it generation and pollution of sewage also increased continuously. Due to high organic and salt load of untreated sewage, its disposal in water bodies causes water pollution. Almost all of our major rivers are now threatened with such problems. With these grim realities, application of sewage in agricultural land offers a promising alternative as sewage is rich in substitute for the freshwater for irrigation.

In this chapter, an attempt has been made to bring a review of the published work related to the present investigation. While consolidating the results from technical reports and research papers from India and abroad, various aspects of land treatment have been considered separately with emphasis on the land application as a rational, waste treatment and disposal alternative. In the review, the term 'effluent', 'waste water', and 'municipal sewage' are used synonymously.

2.1 Potential of Sewage Waste Water

Nutrient supplying potential of sewage is directly related to its consumption, which in turn depends on the extent of industrialization and urbanization of the area from where sewage is generated. The physico-chemical analysis of the wastewater revealed that the amount of sodium, potassium, calcium, Iron, chloride, sulphate ions and the degree of electrical conductivity were often above the limits of the standards for irrigation water for agricultural land (Datta et al, 2000, Gadallah, 1996, Ayuso et al, 1996 and Kandhasamy and Santhaguru, 1994).

It is well known that the domestic sewage is rich in nutrients. These nutrients are mainly found in organic form with high amount of dissolved and suspended solids. Such effluents when discharged into an open drain undergo decomposition and create foul and unpleasant smell. The sewage thus poses a serious environmental pollution problem because of its high BOD (Thanunathan et al, 2000, Kaushik et al, 1991 and Klimo and Fekete, 1990) there by endangering aquatic life.

2.2 Effect Of Sewage Wastewater On Soil Properties

Depending upon the concentration of sewage and the crop system raised, soil accumulation of varying concentration of different chemical species is expected over continuous sewage application. Literature is abounding with reviews which

reviewed the probable effects of wastewater irrigation on soil properties in enough length. Evaluating the properties of the soil irrigated with wastewater found significant increase in concentration of soluble salts, nitrates and phosphates over those values obtained for well water-irrigated soil.

Hundal and Sandhu (1990) revealed a significant decrease in pH and increase in electrical conductance and organic matter in soils irrigated with sewage water while Baddesha et al (1997) observed that irrigation with sewage water for 18 months to Eucalyptus field significantly decreased hydrogen ion concentration and electrical conductivity in the surface soil layers. However, according to them, application of sewage water significantly increased organic carbon, available nitrogen, phosphorus, potassium, micronutrients, calcium and magnesium, whereas sodium content decreased in the soil surface layer. This could be attributed to the leaching and plant uptake.

Paliwal et al (1998) reported that the soil hydrogen ion concentration was increased to maximum in the 50% and 100% sewage water treatment. The increase in hydrogen ion concentration of soil may be due to the sewage irrigation and accumulation of calcium and sodium. He also observed that the elements such as nitrogen, phosphorus and sodium in soil accumulate more than control when the levels of sewage water concentration increased, thereby responsible for increased hydrogen ion concentration. The accumulation of heavy metals in soils and their subsequent uptake by plants represent the greatest potential problem of sewage disposal on agricultural land. The level of metal and other elements resending from 75 days of irrigation with sewage water in the following order $N > Mg > K > Na$. This was probably due to the differences in their concentration in the sewage water.

Gupta et al (1993) observed that the post harvest soil organic carbon content remained unaffected with the application of phosphorus and increased with the application of sewage sludge. The increase in organic carbon with the application of sewage sludge or sewage water was due to the addition of carbonaceous material present in the sludge or sewage wastewater has been reported by Singh and Varloo (1996), Paulraj and Ramulu (1994), Gupta et al (1993), Juwarker et al (1994), Hundal and Sandhu (1990) and Abdou and Nennah (1980).

Chakrabarti (1995) conducted a field study of the effect of sewage water on soil and found that the total potassium content of the soil remained unaffected. However, there was a slight decrease in total nitrogen and phosphorus content of the soil. Furthermore, the regular application of municipal waste water or industrial effluent leads to accumulation of heavy metals in the soil as per the reports of Paul Raj and SreeRamulu (1994) and Narwal et al (1995).

The application of sewage water increased total nitrogen, phosphorus, potassium, sodium, iron, calcium and magnesium was also found by many workers (Paliwal et al, 1998 and Juwarkar et al, 1994). Paulraj and Ramulu (1994) recorded higher available nitrogen, phosphorus and potassium contents in the post harvest soil with application of sewage sludge over control. Baddesha et al (1997) also observed increased available nitrogen, phosphorus, potassium, micronutrients, calcium and magnesium but decreased soluble sodium content in the soil with application of sewage waste.

2.3 Effect of Sewage Waste Water on Different Crops

As has been emphasised earlier, in the initial stages of sewage application on land, the practice was meant merely a disposal mean. Appreciation of the presence of vast quantities of available plant nutrients added a new dimension to this method as an efficient way of nutrient recovery through crop production. A host of informative reports appeared in the past few decades to illustrate the influence of the sewage effluents irrigation on crop yields. A large number of sewage farms which were put under efficient operation and proper management recorded spectacular increases in crop yields. An introspection of the scientific world regarding the effect of sewage wastewater on different crops are given as under.

Germination and seedling growth of any plant is one of the decisive factor for determining its establishment and success in a set of environmental factors. Sewage water have been reported to affect the germination of the seeds to a great extent. Sewage water before dilution showed an inhibitory effect, while after treatment or after dilution showed stimulatory effect. Shukla and Moitra, (1995) and Singh (1982) observed that toxic components of any industrial wastewater on coming in contact with a germinating seeds cause damage to the seed and plant yields.

Veer and Lata (1987) and Billore and Reddy (1988) observed that forage crops, grasses and monocots were grown successfully in the presence of municipal wastewater. So germination of seeds not only depends on the concentration but also on the nutrient composition of the water.

Sewage water significantly influenced the growth performances of the plants. The shoot length, root length and root collar diameter increased with the 25, 50 and 75% sewage water treatment but the adverse effect of excessive salts in the raw sewage water might have been responsible for the reduction in plant growth (Varadarajan, 1992).

Singh and Singh (1985) also reported that application of sewage waste inhibit the percent germination which might be due to toxic component of sewage water which on coming in contact with a germinating seed may enter the body system and resulting in ultimate damage to the seed.

Quantitative estimation of chlorophyll is one of the important parameters of structural aspects of the ecosystem and may be considered as an index of primary productivity in the ecosystem (Odum et al, 1958) since it is the actual place of photosynthetic activity, it is important to calculate standing crop pigments of the standing crop in any plant community. The total chlorophyll in the whole plant community has been reported to be more uniform than individual plant or plant parts (Gessner, 1949). A number of studies have been reported on the total chlorophyll and production of plant communities in different climatic regions of the world (Ovington et al, 1963).

Sewage waste water was reported to cause inhibitory impact on the photosynthesis in many crop plants (Agarwal and Agarwal, 1990 and Kaur and Duffus, 1989) but beneficial effect of diluted waste water from industries, has also been well documented by Sahai et al (1983). Paliwal et al (1988) observed that sewage soil promoted chlorophyll synthesis, while net photosynthesis was unaltered. However, seedling treated with high concentration of sewage water showed reduced chlorophyll synthesis. This could be due to the presence of heavy metals which interfere with the protochlorophyllide reductase complex and the synthesis of amino levulinic acid (Prasad and Prasad, 1987).

Nitrate is the predominant form of nitrogen available to the crop plants in normal field conditions and productivity of any plant is largely influenced by the acquisition and reduction of nitrate nitrogen and its incorporation into amino acids and proteins. Nitrate reductase, localized in the cytoplasm, is the first enzyme in the pathway of nitrate assimilation and catalyzes the reduction of nitrate to nitrite which is further reduced to ammonium by nitrite reductase in the chloroplast. Thus, Nitrite reductase and nitrate reductase are two key enzymes involved in nitrate assimilation.

Nitrate reductase activity has been considered to be much affected by increase in sewer water concentration. Sewer water is rich in ionic content, hence, inhibited the nitrate reductase activity due to the presence of excessive ions in the sewer water (Muthuchelian et al, 1988).

The availability of NO_3^- to the nitrate reductase enzyme is the main factor limiting the entire NO_3^- assimilation process. The cytosolic content of NO_3^- is responsible of the increase of nitrate reductase expression and activity (Tischner et al, 1993). Increase in nitrogen content increased the nitrate reductase activity (Santos et al, 1992) as well as nitrate reductase activity increased with high NO_3^- content and decreased with low NCV content (Hernandez et al, 1995).

Paliwal et al (1998) reported depressed nitrate reductase activity in sewage soil grown plants which showed the unavailability of nitrate in the sewage soil rather than metal inactivation on nitrate reductase enzyme. A significant decrease in nitrate reductase activity as a result of sewage irrigation (Sundararajan et al, 1994) could be due to high amount of nitrogen level in sewage. This could be related to more availability of ions in sewage water (Muthuchelian et al, 1988). Reduction in nitrate reductase activity, therefore can be considered as the best biochemical indicator for sewage pollution.

III. MATERIALS AND METHODS

3.1 Description of The Study Area

Nagpur district is one of the nine districts of Vidarbha Region of Maharashtra State. It is situated on the eastern part of the State abutting Chindwada district of Madhya Pradesh in north. It is bounded by Wardha and Amravati districts in

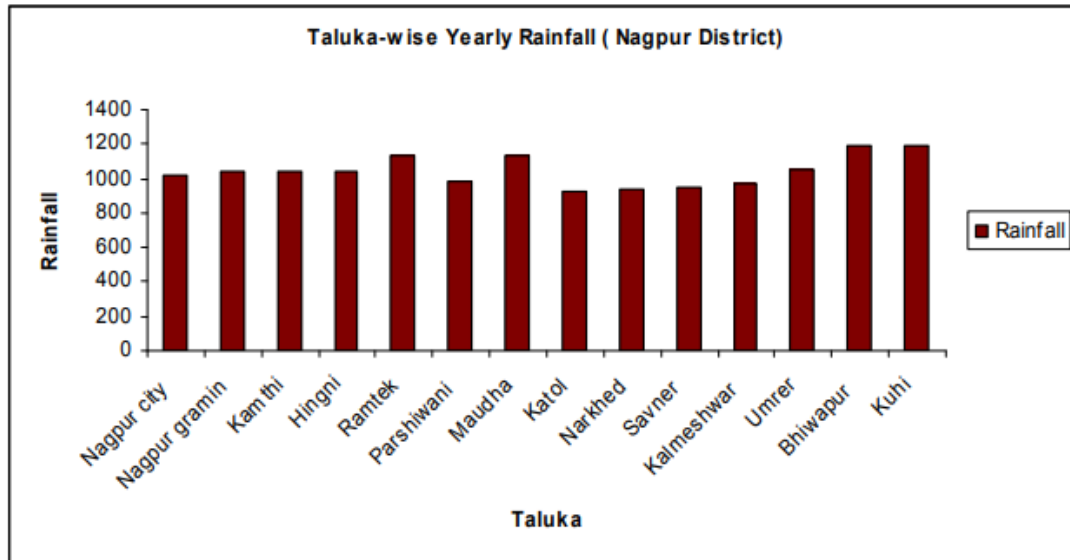
the west, Bhandara district in the east and Chandrapur district in the south. It lies between north latitudes $20^{\circ}35'$ and $21^{\circ}44'$ and east longitudes $78^{\circ}15'$ and $79^{\circ}40'$ and falls in Survey of India topo-sheets 55 K, O and P. The district has a geographical area of 9892 sq. km.

The district headquarters is located at Nagpur Town. For Administrative convenience, the district is divided in 14 talukas viz, Nagpur (Urban), Saoner, Parseoni, Ramtek, Mouda, Kamthi, Kuhi, Bhiwapur, Umrer, Nagpur (Rural), Hingna, Katol, Narkhed and Kalmeshwar. It has a total population of 40.51 lakh as per 2001 census. The district has 29 towns, 1562 inhabited villages and 312 uninhabited villages. The district forms part of Godavari basin. Wainganga River is the main river flowing through the district.

The climate of the district is characterized by a hot summer and general dryness throughout the year except during the south-west monsoon season, i.e., June to September. The mean minimum temperature is 12°C and mean maximum temperature is more than 45°C . The normal annual rainfall (1901-1992) over the district ranges from about 1000 mm to 1200 mm. It is the minimum in the western parts around Katol (985.4mm) and increases in the eastern direction and reaches a maximum around Umrer (1213.6 mm). Rainfall data from 14 rain gauge stations for the periods 2002-2011 are given in table 3. The average annual rainfall for the last 10 years ranges from 753.9 in Hingni to 1164.9 in Umrer. It is also observed that all stations have recorded average annual rainfall within the range of district normal annual rainfall except at Hingni, Katol, Narkhed and Kalmeshwar where it is less than .



Fig.3.1 :Map of Nagpur District



District Nagpur		
Taluka	Rainfall	Rainy Day
Nagpur city	1020.9	62.8
Nagpur gramin	1045.0	54.2
Kamthi	1045.0	52.1
Hingni	1045.0	52.1
Ramtek	1133.0	52.1
Parshiwani	986.0	52.1
Maudha	1133.0	52.1
Katol	921.0	52.1
Narkhed	940.0	52.1
Savner	945.8	57.8
Kalmeshwar	976.0	52.1
Umrer	1055.3	59.6
Bhiwapur	1196.0	52.1
Kuhi	1196.0	52.1
Overall	1045.6	54.0

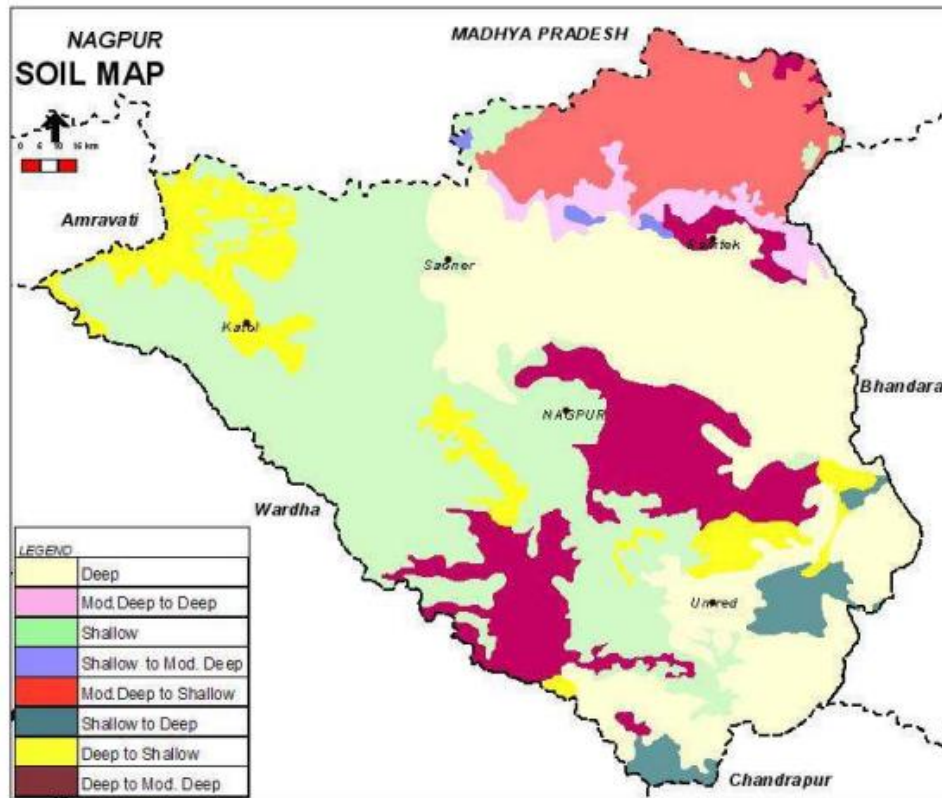


Fig.3.2 : Soil Map (Source: NBSS & LUP, Nagpur)

3.2 Analysis of Physico-Chemical Properties of Sewage Waste Water Samples

Sewage waste from a depth of about 0-10 inches was collected in plastic bottle by directly dipping the bottle into the water. The sewage water were analyzed for different physicochemical properties viz. Total dissolved solids, hydrogen ion concentration, electric conductivity, Calcium, Magnesium, Hardness, Phosphorus, Sodium, Potassium, Ferrous (Iron), Alkalinity, Chloride, Free CO₂, Dissolved oxygen, Sulphate, Carbonate, Bicarbonate.

3.3 Analysis of Physico-Chemical Properties of Soil Samples

Soil sample collected from the natural site (0-15 cm. depth) were air dried, sieved through a 2m.m.mesh and homogenized. The soil samples were analyzed for different physico-chemical properties viz. Bulk density, Specific gravity, Moisture content, Water holding capacity, hydrogen ion concentration, electric conductivity, Calcium, Magnesium, Hardness, Phosphorus, Sodium, Potassium, Ferrous (Iron), Alkalinity, Chloride, Free carbondioxide, Dissolved oxygen, Sulphate, Carbonate, Bicarbonate, Nitrogen, Organic matter, Dehydrogenase activity, Cation exchange capacity, Hydraulic conductivity.

3.4 Responses of Different Crop Plant Species to Sewage Waste Water

The plants were grown in polythene bags containing 8.5 kg air dried soil. Five plants were selected to grow in each pot. Two weeks after germination the water used for irrigation was replaced by sewage water in two concentrations i.e. 50% and 100% sewage water. The control plants were irrigated with tap water. The crop plant species viz. Triticumaestivum var. WH-147, Brassica campestris var. RH-30, Hordeum vulgare var. BH-75, Sorghum vulgare var. Ramganj, Pennisetumtyphoides var. Nandi-3 and Zea mays var. KH-101, were taken for the present study. The experiments were conducted in culture dishes and pot culture.

Seed germination and seedling growth experiments:

Seed germination experiments were conducted in petridishes using sewage waste for all the rabi and kharif crop plant species selected. The seeds were washed with 100ml of HgCl₂ solution for five minutes. Then the seeds were washed for one hour under running water. The sewage waste was used in two different concentration i.e. 50% and 100% sewage waste along with the control. For each treatment, 10 seeds were kept in petridishes at uniform distance on blotting papers, moistened with 10ml of the respective solution and kept at 25±3°C temperature inside the B.O.D. incubator. 10ml of tap water and sewage wastewater was supplied regularly. Each treatment had three replicates. The counting of the germinating seeds was done after 24, 48 and 72 hours after sowing, there was no further germination after 72 hours. Emergence of both radical and plumule was taken as the induction of germination. The seedling growth was measured in terms of the length of the radical and plumule by using meter scale, on 4th, 6th, 8th and 10th days after sowing.

Pot culture experiment:

Effect of sewage waste on the nutrient uptake and growth of rabi and kharif crops of Haryana were studied using pot culture. The pot culture experiments were conducted using polythene bags as pots of size 30cm x 20cm. The study continued for a period of one year. Soil sample collected from the natural site (0-15 cm depth) were air dried, sieved through 2mm mesh and homogenized. Weighed quantities (8.5 kg/ pot) of soil filled up in all the pots.

Table 3.1: Details of treatments (for rabi as well as kharif crops).

Crop Plant Species	Sewage Concentrations		
	0%	50%	100%
<i>Triticum aestivum</i>	S ₀ W	S ₂ W	S ₁ W
<i>Brassica campestris</i>	S ₀ M	S ₂ M	S ₁ M
<i>Hordeum vulgare</i>	S ₀ J	S ₂ J	S ₁ J
<i>Sorghum vulgare</i>	S ₀ Jr	S ₂ Jr	S ₁ Jr
<i>Pennisetum typhoides</i>	S ₀ B	S ₂ B	S ₁ B
<i>Zea mays</i>	S ₀ Mz	S ₂ Mz	S ₁ Mz

A pre-sowing irrigation was given to prepare the field. The soil was puddled twice and labelled, and then, the seeds were sown at the seed rate of ten seeds per pot at random. The seeds are placed about 3-4 cm. depth. The gap filling or thinning was done within second week after emergence. This was done to maintain uniform plants in the pots. The first irrigation was given at 3 weeks after sowing and subsequent irrigation was applied at flowering stage of the crop.

The experiment was laid out in a block design with three replications. The plan of layout is presented in Figure 3.2. The details of the treatment for rabi and kharif crops are shown in Table 3.1. A total of 54 pots were grouped as 6 crop plant species x 3 sewage concentrations x 3 replicates = 54.

Estimation of chlorophyll and carotenoids:

Fresh plant leaves (25mg) were extracted with 80% acetone and centrifuged at 3000 r.p.m. for 20 minutes. Extraction and centrifugation were repeated till the residue become colourless. Amount of supernatant was made upto 10 ml. with acetone (80%) and absorbance of supernatant was recorded at 665 nm, 645nm and 440 nm for Chlorophyll 'a', Chlorophyll 'b' and carotenoids respectively.



Figure 3.3: Plan of Layout

Calculations Chlorophyll and carotenoid contents were calculated following the formula given by Arnon (1949) as follows: -

$$\begin{aligned} \text{Chlorophyll 'a'} &= 11.63 \times \text{O.D.}_{665} - 2.39 \times \text{O.D.}_{645} \times \frac{V}{1000 \times W} \\ (\text{mg/g.f.wt.}) & \\ \text{Chlorophyll 'b'} &= 20.11 \times \text{O.D.}_{645} - 5.18 \times \text{O.D.}_{665} \times \frac{V}{1000 \times W} \\ (\text{mg/g.f.wt.}) & \\ \text{Total Chlorophyll} &= 6.45 \times \text{O.D.}_{665} + 17.75 \times \text{O.D.}_{645} \times \frac{V}{1000 \times W} \\ (\text{mg/g.f.wt.}) & \\ \text{Carotenoids (mg/g.f.wt.)} &= \text{O.D.}_{440} \times V \times F \times \frac{10}{2500} \end{aligned}$$

Where, W= Weight of sample (g.) V= Total volume in ml. F= Dilution factor. 2500= An average extinction coefficient for carotenoids. All the values were converted in terms of per unit fresh weight of the plant material.

Enzyme assay: Nitrate reductase

Nitrate Reductase activity in vivo was assayed in the fresh plant material by the method of Srivastava (1975). 500mg fresh leaves were incubated in an assay medium, containing 8.0 ml. of 0.1 M sodium phosphate buffer (pH=7.4), 1.0 ml. of 2M KNO₃ and 1.0ml of 25% n-propanol in dark coloured 15 ml vials. The vials were sealed and incubated in dark for 30 min at 30°C. Nitrite released in the incubation mixture due to enzyme activity was measured by colour development. From the above enzyme assay 2ml aliquot was drawn out, followed by the addition of 2.0 ml of 10 % Sulphanilamide in 1.0 N HCl (w/v) and 2.0 ml of 0.02% N- (1-Naphthyl) ethylene diamine dihydrochloride (NED). Absorbance of the pink colour developed read at 540 nm after 20 min. A standard curve was prepared using different concentration of sodium nitrite.

Protein estimation:

The method for estimation of total protein was Lowry et al (1951) in which BSA (bovine serum albumin) used as standard. The protein was precipitated with 20% TCA and kept for 30 min. and centrifuged at 5000 r.p.m. Then the precipitated were washed with acetone, dissolved in 0.1 N NaOH and made to 5ml Volume. 2ml aliquot of NaOH extract, 5ml. of alkaline copper solution and 0.5 ml. of folin's phenol reagent was added. After mixing well, the solution was allowed to stand for 30min at room temperature. The optical density was measured at 570 nm at spectronic-20.

Sugar estimation:

Sugars were measured by anthrone reagent method of Chopra and Kanwar (1991).

100 mg of fresh plant material was extracted with 2ml of 80% ethanol and centrifuged to collect supernatant. The extraction was repeated again with 2ml of 80% ethanol. The supernatant was collected and the total volume was made upto 4 ml with distilled water. For estimating the amount of sucrose, 0.1 ml of the supernatant and 0.1 ml of 30% KOH were added in the test tube and covered with aluminium foil. Heated the contents at 100°C for 10 minutes. Cooled them to room temperature. Then 3 ml anthrone reagent was added and kept at 40°C for 10-15 min. Absorbance was measured at 620nm. A standard curve was prepared by various concentrations of pure sucrose.

Organic carbon:

The plant organic carbon was estimated by Rapid titration method of Walkley's and Black (1934). 0.050g oven dried, ground and sieved plant material was taken in 500 ml titration flask, to which 20 ml of 1N K₂Cr₂O₇ solution and 20 ml concentrated sulphuric acid were added. After half an hour the contents of flask was diluted with 200 ml. distilled water followed by the addition of 10 ml orthophosphoric acid (85%) and 1ml of diphenyl indicator and then titrated it against 1N ferrous ammonium sulphate solution.

At the end point, dark blue colour changed to grassy green. A blank was also run simultaneously in order to standardize the normality of the ferrous ammonium sulphate solution used.

Calculations Plant organic carbon was calculated as follows: -

Plant organic carbon was calculated as follows: -

$$\text{Organic carbon (\%)} = \frac{V_1 - V_2}{\text{Weight of plant material (g)}} \times 0.003 \times 100$$

Where,

V₁ = volume of K₂Cr₂O₇

V₂ = volume of 1N Ferrous ammonium sulphate used.

Organic nitrogen:

Organic nitrogen was estimated according to the modified Kjeldahl method of Lang (1958). 100mg oven dried, plant sample was taken in an 100 ml Kjeldahl flask and digested at 70°C for four hours with 3 ml concentrated H₂SO₄ and a mixture of CuSO₄ (1g) + Selenium powder (1g) + K₂SO₄ (8g) was used as a catalyst, where by all the nitrogen compounds were hydrolyzed and converted to ammonia forms. After digestion 2 ml. of the hydrogen peroxide were added and heated at 70°C for one hour. The digested material was diluted to 100 ml with distilled water.

Total nitrogen converted to ammonia form was determined by nessler's methods of Balentine (1957). An aliquot (0.1ml) of the digested material was treated with 2.5 ml distilled water and 2 ml of Nessler's Reagent. The optical densities of the solutions were measured at 440 nm after 20 minutes using spectrophotometer. The concentration of the nitrogen in the original material was collected after obtaining the nitrogen in the sample aliquots from calibration curves, prepared by using a range of standard NaNC>3 solution.

IV. RESULTS

4.1 Characterization of the sewage waste water

The sewage waste water was analyzed for different physico-chemical properties viz. total dissolved solids, hydrogen ion concentration, electric conductivity, calcium, magnesium, hardness, phosphorus, sodium, potassium, iron, alkalinity, chloride, free carbon dioxide, dissolved oxygen, sulphate, carbonate and bicarbonate from the Nagpur Rural Areas and the results were shown in Table 4.1. The sewage waste water exhibited almost neutral hydrogen ion concentration value (pH=7.6) and very high electrical conductivity (1.82 m.mhos/cm) than the standard set up to (0.25-0.33 m.mhos/cm) at 25°C. Large amounts of total dissolved solids (2280 mg/L) were found in the sewage waste water as compared to standard value. Almost all the physico-chemical properties of sewage waste water comparatively higher value than the standard values. The sodium, potassium and chloride contents were quite high amounting to 415.61 mg/L, 58.75 mg/L, 70.91 mg/L respectively. Amongst the other cations calcium (98.26mg/L) was higher in concentration than magnesium (31.72 mg/L), however, total hardness was found to be 240.62 mg/L. Ferrous was slightly higher (1.26 mg/L) in the sewage effluent.

Amongst the anions, the sewage effluent was rich in sulphates and phosphorus (325.68 mg/L and 8.47 mg/L respectively). An alkalinity (244.78 mg/L) of the effluent seems to be due to bicarbonates (165.03 mg/L) only because carbonates were not observed in the effluent. Free CO₂ level in the sewage effluent was more (32.14 mg/L) whereas dissolved oxygen was not observed which showed the absence of flora and fauna in the sewage effluent.

Table 4.1 Physico-chemical properties of sewage waste water

Parameter	Quantity
Total dissolved solids (mg/L)	2280
pH	7.6
EC (m. mhos /cm)	1.82
Calcium (mg/L)	98.26
Magnesium (mg/L)	31.72
Carbonate (mg/L)	0
Bicarbonate (mg/L)	165.03
Hardness (mg/L)	240.62
Alkalinity (mg/L)	244.78
Phosphorus (mg/L)	8.47
Chloride (mg/L)	70.91
Free CO ₂ (mg/L)	32.14
Dissolved oxygen (mg/L)	0
Sulphate (mg/L)	325.68
Sodium (mg/L)	415.61
Potassium (mg/L)	58.75
Ferrous (mg/L)	1.26

4.2 Characterization of the soil

The soil taken in the pots was analysed for different physico-chemical properties viz. bulk density, specific gravity, moisture content, water holding capacity, hydrogen ion concentration, electric conductivity, calcium, magnesium, hardness, phosphorus, sodium, potassium, ferrous (iron), alkalinity, chloride, free carbondioxide, dissolved oxygen, sulphate, carbonate, bicarbonate, nitrogen, organic matter, cation exchange capacity and hydraulic conductivity which are given in Table 4.2. The soil was sandy loam in texture, of almost normal bulk density and specific gravity, 1.18 g/cm³ and 1.49 respectively. The soil was slightly alkaline (pH=8.12) in nature with very low electric conductivity (0.38 m. mhos/cm).

The sodium contents were lower than the chloride contents, 0.058 mg/L and 0.147 mg/L respectively. Amongst the cations, calcium, magnesium, iron and potassium showed the amount 0.054 mg/L, 0.548 mg/L, 0.056 mg/L and 0.154 mg/L respectively. However, cation exchange capacity was observed to be 8.92 me/100gm of the soil. Amongst the anions sulphate was 0.061 mg/L which was slightly higher than the phosphorus, 0.024 mg/L respectively. The hydraulic conductivity, moisture content, water holding capacity and nitrogen contents were observed slightly higher in the soil which were 19.02 cm/h, 43.25 %, 32.83 % and 0.325 mg/L respectively.

Table 4.2 Physico-chemical properties of (pre-treated) soil

Parameter	Quantity
Bulk Density (g/cm ³)	1.18
Specific gravity	1.49
Hydraulic conductivity (cm/hr)	19.02
Water holding capacity (%)	32.83
Moisture content (%)	43.25
Cation Exchange capacity (me/100gm)	8.92
pH (1-2)	8.12
EC (m.mhos/cm)	0.38
Organic Matter (%)	0.86
Chloride (%)	0.147
Sodium (%)	0.058
Potassium (%)	0.154
Nitrogen (%)	0.128
Phosphorus (%)	0.024
Alkalinity (%)	0.248
Iron (%)	0.056
Calcium (%)	0.054
Magnesium (%)	0.548

4.3 Characterization of the irrigated soils

Application of sewage waste water changed the physicochemical properties of soil after treatment in all the six crop plant species studied which has been shown from Table 4.3 to 4.8. In the soil of Triticumaestivum, hydrogen ion concentration, bulk density and organic carbon significantly decreased with application of sewage waste water at 50% as well as 100% sewage concentrations as compared to control. However, electrical conductivity, water holding capacity, moisture content and hydraulic conductivity significantly increased with the addition of sewage waste water. Similarly, almost all the nutrients sodium, potassium, phosphorus, iron, calcium and magnesium of the soil increased with application of sewage waste water as compared to control.

Table 4.3 Effect of sewage waste on physico-chemical properties in soil of *Triticumaestivum*

Parameter	Sewage Concentrations		
	0%	50%	100%
Bulk Density (g/cm^3)	1.181 \pm 0.20	1.168 \pm 0.26 [*]	1.147 \pm 0.20 ^{**}
Specific Gravity	1.523 \pm 0.11	1.531 \pm 0.12 ^{NS}	1.528 \pm 0.18 ^{NS}
Hydraulic conductivity (cm/hr)	19.04 \pm 1.54	19.17 \pm 1.09 ^{NS}	19.44 \pm 2.10 [*]
Water holding capacity (%)	34.24 \pm 2.64	36.45 \pm 2.81 [*]	38.28 \pm 2.26 ^{**}
Moisture content (%)	43.47 \pm 3.61	44.29 \pm 4.19 [*]	45.87 \pm 4.13 [*]
Organic Matter (%)	0.85 \pm 0.16	0.83 \pm 0.13 ^{NS}	0.75 \pm 0.17 [*]
Cation Exchange capacity (me/100gm)	9.21 \pm 0.58	9.83 \pm 0.80 [*]	10.43 \pm 0.97 ^{**}
PH (1:2)	8.12 \pm 0.20	8.01 \pm 0.24 [*]	7.92 \pm 0.33 [*]
EC (m.mhos/cm)	0.43 \pm 0.09	0.45 \pm 0.02 ^{NS}	0.56 \pm 0.03 [*]
Sodium (%)	0.047 \pm 0.07	0.054 \pm 0.08 [*]	0.059 \pm 0.09 ^{**}
Potassium (%)	0.134 \pm 0.20	0.154 \pm 0.41 ^{**}	0.156 \pm 0.58 ^{**}
Nitrogen (%)	0.159 \pm 0.22	0.182 \pm 0.30 ^{**}	0.234 \pm 0.22 ^{**}
Phosphorus (%)	0.28 \pm 0.10	0.35 \pm 0.10 [*]	0.43 \pm 0.08 ^{**}
Iron (%)	0.053 \pm 0.15	0.069 \pm 0.10 ^{**}	0.076 \pm 0.12 ^{**}
Calcium (%)	0.113 \pm 0.07	0.126 \pm 0.07 ^{**}	0.134 \pm 0.10 ^{NS}
Magnesium (%)	0.121 \pm 0.08	0.123 \pm 0.09 ^{NS}	0.125 \pm 0.07 ^{NS}

Table 4.4 Effect of sewage waste on physico-chemical properties in soil of *Brassica campestris*

Parameter	Sewage Concentrations		
	0%	50%	100%
Bulk Density (g/cm^3)	1.183 \pm 0.19	1.172 \pm 0.21 [*]	1.152 \pm 0.23 ^{**}
Specific Gravity	1.517 \pm 0.12	1.536 \pm 0.15 ^{NS}	1.524 \pm 0.14 ^{NS}
Hydraulic conductivity (cm/hr)	19.04 \pm 1.87	18.17 \pm 2.04 ^{**}	17.46 \pm 2.12 ^{**}
Water holding capacity (%)	33.20 \pm 2.65	37.64 \pm 2.87 ^{**}	39.31 \pm 3.21 ^{**}
Moisture content (%)	44.17 \pm 3.41	46.23 \pm 4.15 [*]	49.67 \pm 4.19 ^{**}
Organic Matter (%)	0.89 \pm 0.11	0.96 \pm 0.15 ^{**}	1.15 \pm 0.12 ^{**}
Cation Exchange capacity (me/100gm)	8.91 \pm 0.57	9.62 \pm 0.87 [*]	10.48 \pm 0.91 ^{**}
PH (1:2)	8.06 \pm 0.25	7.91 \pm 0.28 [*]	7.83 \pm 0.38 ^{**}
EC (m.mhos/cm)	0.42 \pm 0.04	0.53 \pm 0.08 ^{**}	0.68 \pm 0.09 ^{**}
Sodium (%)	0.037 \pm 0.02	0.046 \pm 0.04 [*]	0.049 \pm 0.03 ^{**}
Potassium (%)	0.126 \pm 0.23	0.148 \pm 0.46 ^{**}	0.172 \pm 0.52 ^{**}
Nitrogen (%)	0.168 \pm 0.29	0.242 \pm 0.36 ^{**}	0.276 \pm 0.27 ^{**}
Phosphorus (%)	0.26 \pm 0.05	0.39 \pm 0.04 ^{**}	0.35 \pm 0.02 ^{**}
Iron (%)	0.049 \pm 0.12	0.063 \pm 0.16 ^{**}	0.066 \pm 0.17 ^{**}
Calcium (%)	0.108 \pm 0.02	0.096 \pm 0.03 ^{**}	0.124 \pm 0.08 ^{NS}
Magnesium (%)	0.128 \pm 0.04	0.123 \pm 0.05 ^{**}	0.115 \pm 0.03 [*]

In the soil of *Brassica campestris*, hydrogen ion concentration, bulk density and hydraulic conductivity significantly decreased with application of sewage waste water at 50% as well as 100% sewage concentrations as compared to control. However, electrical conductivity, water holding capacity, moisture content and organic carbon significantly

increased with the addition of sewage waste water, whereas, specific gravity showed the non-significant increase as compared to control. Almost all the nutrients sodium, potassium, nitrogen, phosphorus, iron and calcium, of the soil increased with application of sewage waste water as compared to control, while magnesium of the soil was decreased at 50% and 100% sewage concentrations.

In the soil of *Hordeum vulgare*, application of sewage waste water significantly decreased the hydrogen ion concentration, bulk density and hydraulic conductivity at 50% as well as 100% sewage concentrations as compared to control. However, electrical conductivity, water holding capacity, moisture content and organic carbon significantly increased with the addition of sewage waste water, whereas, specific gravity showed the non-significant increase as compared to control. Almost all the nutrients sodium, potassium, nitrogen, phosphorus, iron and calcium, of the soil increased with application of sewage waste water as compared to control, while magnesium of the soil was decreased at 50% and 100% sewage concentrations.

In the soil of *Sorghum vulgares*, hydrogen ion concentration, bulk density and hydraulic conductivity significantly decreased with application of sewage waste water at 50% as well as 100% sewage concentrations as compared to control. However, electrical conductivity, water holding capacity, moisture content and organic carbon significantly increased with the addition of sewage waste water, whereas, specific gravity showed the non-significant increase as compared to control. Almost all the nutrients sodium, potassium, nitrogen, phosphorus, iron, calcium and magnesium, of the soil increased with application of sewage waste water as compared to control.

In the soil of *Pennisetum typhoides*, hydrogen ion concentration, bulk density and organic matter significantly decreased with application of sewage waste water at 50% as well as 100% sewage concentrations as compared to control. However, electrical conductivity, water holding capacity, moisture content and hydraulic conductivity significantly increased with the addition of sewage waste water. Similarly, almost all the nutrients sodium, potassium, phosphorus, iron, calcium and magnesium of the soil increased with application of sewage waste water as compared to control.

In the soil of *Zea mays*, application of sewage waste water significantly decreased the hydrogen ion concentration, bulk density and hydraulic conductivity at 50% as well as 100% sewage concentrations as compared to control. However, electrical conductivity, water holding capacity, moisture content and organic carbon significantly increased with the addition of sewage waste water, while, specific gravity showed the non-significant increase as compared to control. Almost all the nutrients sodium, potassium, nitrogen, phosphorus, iron, calcium and magnesium, of the soil increased with application of sewage waste water as compared to control.

Table 4.5 Effect of sewage waste on physico-chemical properties in soil of *Hordeum vulgare*

Parameter	Sewage Concentrations		
	0%	50%	100%
Bulk Density (g/cm ³)	1.179±0.11	1.174±0.13 [*]	1.160±0.17 [*]
Specific Gravity	1.524±0.14	1.529±0.12 ^{NS}	1.527±0.11 ^{NS}
Hydraulic conductivity (cm/hr)	19.44±1.17	18.97±1.44 ^{**}	18.46±1.17 ^{**}
Water holding capacity (%)	33.28±2.1	36.68±2.57 ^{**}	38.37±2.24 ^{**}
Moisture content (%)	45.17±2.7	46.93±2.14 [*]	48.74±2.19 ^{**}
Organic Matter (%)	0.87±0.08	1.11±0.06 ^{**}	1.19±0.14 ^{**}
Cation Exchange capacity (me/100gm)	8.41±0.27	8.68±0.77 [*]	9.47±0.82 ^{**}
PH (1:2)	8.1±0.22	8.01±0.16 [*]	7.96±0.43 ^{**}
EC (m.mhos/cm)	0.46±0.07	0.64±0.09 ^{**}	0.69±0.06 ^{**}
Sodium (%)	0.046±0.11	0.052±0.07 [*]	0.064±0.07 ^{**}
Potassium (%)	0.122±0.18	0.139±0.41 ^{**}	0.162±0.42 ^{**}
Nitrogen (%)	0.161±0.19	0.254±0.28 ^{**}	0.275±0.17 ^{**}
Phosphorus (%)	0.32±0.08	0.38±0.05 [*]	0.45±0.04 ^{**}
Iron (%)	0.054±0.24	0.069±0.17 ^{**}	0.072±0.13 ^{**}
Calcium (%)	0.98±0.07	0.099±0.06 ^{NS}	0.116±0.09 [*]
Magnesium (%)	0.121±0.05	0.118±0.04 [*]	0.109±0.05 [*]

Table 4.6 Effect of sewage waste on physico-chemical properties in soil of *Sorghum vulgare*

Parameter	Sewage Concentrations		
	0%	50%	100%
Bulk Density (g/cm ³)	1.185±0.12	1.182±0.28 [*]	1.167±0.26 ^{***}
Specific Gravity	1.519±0.17	1.523±0.20 ^{NS}	1.529±0.19 ^{NS}
Hydraulic conductivity (cm/hr)	19.13±1.80	19.11±2.08 ^{NS}	18.56±2.16 ^{***}
Water holding capacity (%)	33.45±2.60	37.15±2.89 ^{***}	38.32±3.24 ^{***}
Moisture content (%)	44.87±3.46	46.13±4.10 [*]	48.64±3.12 ^{***}
Organic Matter (%)	0.84±0.16	0.91±0.18 [*]	1.05±0.16 ^{***}
Cation Exchange capacity (me/100gm)	8.41±0.50	9.32±0.89 [*]	10.12±0.95 ^{***}
PH (1:2)	8.21±0.29	8.11±0.21 [*]	7.99±0.32 ^{***}
EC (m.mhos/cm)	0.49±0.07	0.53±0.02 ^{***}	0.65±0.05 ^{***}
Sodium (%)	0.046±0.09	0.049±0.08 ^{NS}	0.054±0.07 [*]
Potassium (%)	0.135±0.20	0.140±0.40 ^{NS}	0.179±0.56 ^{***}
Nitrogen (%)	0.162±0.23	0.221±0.32 ^{***}	0.236±0.20 ^{***}
Phosphorus (%)	0.24±0.10	0.38±0.09 ^{***}	0.43±0.08 ^{***}
Iron (%)	0.042±0.16	0.058±0.10 ^{***}	0.068±0.20 ^{***}
Calcium (%)	0.115±0.08	0.099±0.06 [*]	0.121±0.12 [*]
Magnesium (%)	0.121±0.06	0.129±0.10 [*]	0.123±0.08 ^{NS}

Table 4.7 Effect of sewage waste on physico-chemical properties in soil of *Pennisetum typhoides*

Parameter	Sewage Concentrations		
	0%	50%	100%
Bulk Density (g/cm ³)	1.188±0.14	1.172±0.26 [*]	1.158±0.21 ^{***}
Specific Gravity	1.512±0.18	1.536±0.10 ^{NS}	1.545±0.19 ^{NS}
Hydraulic conductivity (cm/hr)	19.04±1.82	19.16±2.07 ^{***}	19.46±2.18 ^{***}
Water holding capacity (%)	33.20±2.68	37.27±2.82 ^{***}	38.31±3.27 ^{***}
Moisture content (%)	43.57±3.45	44.23±4.11 [*]	45.67±4.14 ^{***}
Organic Matter (%)	0.87±0.16	0.81±0.18 [*]	0.76±0.16 ^{***}
Cation Exchange capacity (me/100gm)	9.96±0.53	9.82±0.82 [*]	10.43±0.98 ^{***}
PH (1:2)	8.16±0.28	8.00±0.23 [*]	7.93±0.35 ^{***}
EC (m.mhos/cm)	0.45±0.06	0.58±0.02 [*]	0.75±0.14 ^{***}
Sodium (%)	0.045±0.08	0.059±0.09 [*]	0.072±0.06 ^{***}
Potassium (%)	0.120±0.27	0.171±0.42 ^{***}	0.196±0.58 ^{***}
Nitrogen (%)	0.162±0.33	0.212±0.31 ^{***}	0.216±0.21 ^{***}
Phosphorus (%)	0.21±0.08	0.47±0.06 ^{***}	0.49±0.05 ^{***}
Iron (%)	0.044±0.17	0.053±0.10 [*]	0.056±0.12 ^{***}
Calcium (%)	0.110±0.08	0.123±0.07 ^{***}	0.134±0.15 ^{NS}
Magnesium (%)	0.122±0.06	0.128±0.08 [*]	0.112±0.09 [*]

V. SUMMARY AND CONCLUSION

Disposal of municipal sewage and other sanitary and domestic waste has become one of the principal problems facing modern urban civilization. In most of the Asian countries due to the limited facilities for the treatment of sewage water, the raw sewage is used as such in the agricultural land. The sewage wastewater is discharged on the land for recycling of potential sewage pollutants through the production of agriculture, reclamation of wastewater, minimization of environmental pollution, reducing or eliminating the problems related to sewage handling, storage and disposal, using as a substitute for fresh water for irrigation due to limited water resources. The sewage wastewater is also used to avoid

costly treatment of waste water for discharge as well as the problem of high cost of fertilizer and also for preserving the quality of surface water. However, land treatment cannot guarantee complete safety against hazards from sewage disposal due to manifold problems associated with it, which arises in its course of management.

The differential response was observed for dehydrogenase activity at each interval of time in all the crop plant studied. The dehydrogenase activity in the soil of different crop plant species increased with addition of sewage. Brassica campestris, Hordeum vulgare, Sorghum vulgare and Zea mays showed the maximum dehydrogenase activity at 100% concentration of sewage wastewater, while Triticumaestivum and Pennisetumtyphoides showed the maximum dehydrogenase activity at 50% sewage concentration.

application of sewage wastewater significantly increased the total nitrogen, phosphorus, potassium, cation exchange capacity and organic carbon content of the soil, however, sewage wastewater soils reduced the bulk density, hydraulic conductivity and hydrogen ion concentration of the soil in all the crop plant species except Triticumaestivum and Pennisetumtyphoides.

The increased amount of cations in soils may be due to the fact that the soil possesses a fairly extended buffering capacity which allow ions to accumulate to a certain level. Almost all the metals are by far less mobile and are strongly fixed by humic acids found in the soil. Thus the stimulated photosynthetic rate and chlorophyll synthesis may have stemmed due to the binding nature of soil and the availability of micronutrients.

Sewage wastewater inhibited the germination in all the crop plants, however, 50% sewage concentration enhanced the percent germination in Triticumaestivum, Brassica campestris, Hordeum vulgare and Pennisetumtyphoides. Amongst the different concentrations of sewage, tap water as control showed the maximum percent germination only in Sorghum vulgare and Zea mays.

Triticumaestivum, Brassica campestris and Hordeum vulgare showed similar trend of seedling growth on application of 50% sewage wastewater, while Pennisetumtyphoides and Zea mays showed maximum growth under 100% concentration of sewage wastewater. In case of Sorghum vulgare, both 50% and 100% concentration of sewage wastewater showed adverse effects on radicle as well as plumule length. Thus showing a greater proportion of water absorbing capacity to sewage waste water in Pennisetumtyphoides and Zea mays.

Chlorophyll 'a' content increased with addition of sewage waste in all the crop plants studied except Sorghum vulgare and Brassica campestris at both the sewage concentrations. Similar trend was observed in chlorophyll 'b' and total chlorophyll content.

Percent relative water content is decreased at each interval of time as the plant matures in all the six crop plants studied. Relative water content increased with addition of sewage wastewater and found to be maximum at 50% sewage concentration in all the crop plants except Brassica campestris. Both the sewage concentrations i.e. 50% and 100% showed the adverse effect on the relative water content in Brassica campestris. Such effects could be due to insufficient root system to compensate for water lost by transpiration. The relative water content of two concentrations of sewage wastewater was found to be having significant positive correlation in all the crop plant species studied.

Sewage wastewater showed the adverse effect on the dry matter yield in the most of the crop plants studied. The dry matter yield decreased with the increase in sewage concentration in Triticumaestivum, Hordeum vulgare, Sorghum vulgare and Zea mays. However, increased dry matter yield has been observed in Brassica campestris and Pennisetumtyphoides as compared to control. Maximum dry matter yield has been observed in Zea mays (23.8 g/ pot) under control conditions and found minimum in Hordeum vulgare (14.2 g/ pot) at 100 % sewage concentration. This could be due to higher availability of metal ions in sewage wastewater and also due to imbalances in C:N ratio resulting in decrease in dry matter yield. The dry matter yield in two concentrations of sewage wastewater was found to be significant negative correlation in Triticumaestivum and Sorghum vulgare, however, Hordeum vulgare showed significant positive correlation.

The nitrate reductase activity ranged between 0.49 and 4.97 μ mol N(V / g f. wt./ h. Nitrate reductase activity showed maximum under control conditions, however, 100% sewage concentration showed the minimum nitrate reductase activity in all the crop plants studied. The results concluded that nitrate reductase activity was reduced in the leaves of

all the six crop plant species grown. Nitrate reductase activity reduced due to denitrification of available nitrate by anaerobic bacteria in sewage wastewater with depleted oxygen.

The addition of sewage concentration normally increased the protein content at each interval of time. The application of 100% sewage concentration showed the maximum protein content as compared to control in all the crop plant species except *Hordeum vulgare*, which was found maximum at 50% sewage concentration. The increase may be due to increase in C:N ratio in sewage treated plants. Protein contents showed positive correlation in all the crop plant species studied except *Brassica campestris*, which was found to be having negative correlation between two sewage concentrations.

Sucrose content increased in the leaves of all the six crop plant species at each interval of time under different sewage concentrations and found maximum at 50% sewage concentration in *Triticumaestivum*, *Hordeum vulgare*, *Sorghum vulgare*, *Pennisetumtyphoides* and *Zea mays*. While in *Brassica campestris*, it was found maximum at 100% concentration of sewage wastewater as compared to control. Increase in sucrose contents was due to increase in photosynthetic activities and such a increase in soluble sugars may be an important adaptive response to sewage wastewater. The two concentrations of sewage wastewater showed significant correlation of sucrose contents in all the crop plants.

Organic carbon content increased with increase in sewage concentration in *Triticumaestivum*, *Hordeum vulgare*, *Sorghum vulgare* and *Zea mays*. Whereas, *Brassica campestris* and *Pennisetumtyphoides* showed the decreased organic carbon content. Nitrogen content increased with increase in sewage concentration in all the crop plant species studied except *Hordeum vulgare*.

The addition of sewage waste increased the sodium content in all the crop plants studied. Sodium content has been observed highly significant at ($P < 0.01$) and ($P < 0.001$) respectively, at both the sewage concentrations. The sewage wastewater showed the positive effect on the potassium content in all the crop plant species studied, which ranged between 0.43% and 3.22%. The increase in elements like sodium and potassium increased the uptake of sodium and potassium ions by plant represent the greatest problem of sewage disposal on agricultural land.

The addition of sewage waste slightly increased the calorific content in the grains of all the crop plants studied except *Sorghum vulgare*. The calorific content was found to be in the range from 358.39 KCal /g. to 438.25 KCal /g. The two concentrations of sewage wastewater showed significant positive correlation of calorific contents in *Triticumaestivum*, *Brassica campestris* and *Zea mays*, whereas, *Hordeum vulgare*, *Sorghum vulgare* and *Pennisetumtyphoides* showed the negative correlation.

Differential response of total non-structural carbohydrates in the herbage of all the crop plants has been observed under different sewage concentrations. *Triticumaestivum*, *Hordeum vulgare* and *Zea mays* showed the decreased total non-structural carbohydrates with increase in sewage concentration, while, *Brassica campestris*, *Sorghum vulgare* and *Pennisetumtyphoides* was found to be increased total non-structural carbohydrates with addition of sewage waste.

Conclusively, it can be envisaged that if the waste water is treated adequately or at least diluted with equal amount of water before discharge onto the crop plant premises it can be suitably used by the farmers for irrigation, because of the beneficial effect on the growth, germination and physiological responses of the plants.

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