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Comparative study of some physicochemical parameters of soil irrigated with sewage water and canal water of Dehradun city, India

Swapnil Rai [1*], A.K. Chopra[2], Chakresh Pathak, Dinesh Kr Sharma[1], Renu Sharma[1] and P. M. Gupta[1]

[1]Deptt. of Chemistry, Mangalayatan University, Aligarh(U.P.), India
[2]Department of Zoology and Environmental Science, Gurukula Kangri University, Haridwar, (Uttarakhand), India

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ABSTRACT

In the present study the effect of sewage water and canal water irrigation were compared by their physicochemical properties and heavy metals concentration in soil. The mean values of different physico-chemical parameters and heavy metals were : Bulk density (gm/cm^3) 1.26, Water holding capacity(%)-53.60, Temperature(°C)-16.33, Electrical conductivity (dsm-1)-0.122, pH-7.5, Organic carbon (%)-1.95, Available phosphorous(mg/kg)-108.44, Available potassium (mg/kg)-121.66, Nitrogen(%)-2.22, Available Calcium (%)-2.18, Available Magnesium (%)-0.09 and heavy metal concentration in soil were Pb-52.72, Cu-49.03, Zn-264.09 and Cd-24.66 in sewage water irrigated soil. The observed concentration of Pb, Cu, Zn was below the Indian standards except Cd. The Enrichment factors calculated for sewage water irrigated soil in Pb (3.79), Zn (4.12), Cu (3.12) and Cd (2.21) were moderate enrichment while pollution index values in the samples were calculated to be lower than permissible pollution limit of 1.0.

INTRODUCTION

The most possible sources of soil, water and plant pollutions are sewage sludge, residues of industrial factories and intensive fertilization. In suburban areas, the use of industrial or municipal waste water is common practice in many parts of the world [1,2] including India [3]. The use of sewage effluents for irrigating agricultural land is a worldwide practice [1]. The contamination and quality of irrigation water is of the main concern especially in the regions with limited water resources. In such region not only, the water resources should wisely be utilized at the same time should be prevented from contamination. It is especially common in developing countries, where water treatment cost is high. As there is a gradual decline in availability of fresh water for irrigation in India, the use of sewage and other industrial effluents for irrigating agricultural lands is on the rise [4]. For the farmers, opportunities exist as sewage effluents from domestic origin are rich in organic matter and also contain appreciable amounts of major and micronutrients. Accordingly nutrient levels of soils are expected to increase with continuous irrigation with sewage water [5].

Waste and sewerage water is still considered most rich in plant nutrients and organic matter. In many cities and towns the sewage water is sold and it is a good source of income to municipalities. However, the situation is changed now. Sewage water is available free of cost to adjoining agricultural fields and enriched with macro and micro nutrients required for the plant growth and therefore, farmers prefer the sewage irrigation for saving the cost of fertilizers and irrigation water. Besides nutrients, heavy metals are also present in the sewage water and leads to bio-accumulation of heavy metals in the cultivated crops there in. Bio-accumulation of heavy metals by the crops irrigated with sewage water was also reported by many authors [6] around Sanganer town, Jaipur.

Keeping the above in view the present study has been undertaken to assess the effect of sewage water and canal water irrigation on fertility of soil or changes in the heavy metal concentration and other physicochemical properties of soil due to irrigated with sewage water and canal water of Dehradun city.

MATERIAL AND METHODS

All the samples were collected for sewage water irrigated land from different Sites , situated at Dehradun – Delhi Highway, 5 km from clock tower near the telephone exchange of Dehradun city [Site-I]. It was being irrigated with sewage water and agricultural practices are done in the different plots, and samples for Canal water irrigated land were collected behind Mandi at G.M.S road 6 Km from clock tower of the Dehradun city [Site-II]. It was being irrigated with Bijapur canal water and agricultural practices are done in the different plots. It was considered as control. The soil samples were collected from 3 different plots of each Site with the help of auger. Approximately about 500 gm soil was collected from a depth of 0-15 cm from each Site. The soil samples were taken and placed in a clean polythene bag. Twenty samples were collected from each Site. Various physico-chemical parameters of each land area were analyzed by different techniques [7,8]. and heavy metals were analysed by atomic absorption spectrometer (Perkin Elmer Aanalyst 100) [9].

RESULTS AND DISCUSSION

(a) Physico-chemical parameters:

The mean values ± S.E. and percentage increase and decrease of different physico-chemical parameters viz. temperature, water holding capacity, Bulk density, Available phosphorus, available calcium and Magnesium, total nitrogen of soil at two Sites viz. Site–I and Site–II which were irrigated with sewage water and canal water, respectively are represented in Table–1 and percentile increase/decrease in comparison to control showed by Fig.1 while the heavy metal concentration were showed in Table -2.

The bulk density of soil indicates the degree of compactness of the soil and is defined as the mass per unit volume which includes space occupied by solids and pore space. It decreases with increases in organic matter is more bulk density is reduced. Average value of bulk density at Site–I =1.26±0.00 gm/cm^3 and at Site II=1.83±0.00 gm/cm^3. The bulk density decreased by 31.14% at Site-I in comparison to control Site II, i.e. control.

The water holding capacity is an index of a number of physical properties of soil. Good water holding capacity shows the good physical condition of soil. The uses of sewage water in agriculture increase the water holding capacity [10]. The Site-I showed 53.60±1.90 better water holding capacity than the Site –II 41.58 ±1.90 %, which is 28.90 % more at increase in Site –I in comparison to control Site.

The temperature of soil greatly affects the physical, biological and chemical processes occurring in soils, chemicals and biological rates are slow. Temperature plays a very important role in soil characteristics and seed germination. Temperature regenerates absorption and transport of water and nutrients ions in higher plants [11]. The mean observed values of temperature for Site-I and Site-II were 16.33±1.05^{o}C and 14.50±0.8^{o}C, respectively, which showed increase of 12.62 % at Site-I in comparison to control Site.

The measurement of electrical conductivity is for measure the current that gives a clear idea of soluble salt present in the soil. Conductivity depends upon the dilution of soil suspension. The conductivity of soil of Site-I and Site-II were 0.122 dsm^{-1} and 0.169 dsm^{-1} showed decrease by 27.81 % in sewage water irrigated soil in comparison to control Site.

The measurement of pH shows the acidity and basicity or alkalinity of the soil. From the evidence available, neither a high pH above 8.4 nor a low below 5.0 is favorable for maximum yield of crops. The type of soil controlled by pH value at 6.0-8.2 pH will bacteria predominate [12]. The present findings show that pH at Site–I and II were 7.5±0.00 and 7.9±0.00, respectively. pH decrease by 5.0% at Site–I in comparison to control Site.

Nitrogen is the most important fertilizer element. Plants respond quickly to application of nitrogen. This element encourages above ground vegetative growth and gives a deep green colour to the leaves. Plants roots take up nitrogen in the form of NO_3 and NH_4. In the present study the Site-I showed fairly higher amount of nitrogen (2.22±0.57%) while Site II showed fairly relatively less amount of nitrogen (1.61±0.12%). Thus Site-I showed 37.88% nitrogen than control (Site- II). The overall increase in nitrogen is due to the use of sewage water, which contains high amount of Nitrogen. The sewage water significantly increased the nitrogen in the soil [13]. the high concentration of nitrogen in soil amended with sewage [14].

The source of organic carbon in the cultivated soil included crop residue, animal manure, cover crops, green manure and organic fertilizer etc. Sewage sludge contains 20-40% organic matter of its total dry weight [15]. Thus its uses in agricultural land increase the organic carbon in soil. In the present study Site-I showed fairly higher percentage of organic carbon (1.95±0.00) while Site-II showed relatively less percentage of organic carbon (1.27±0.04%). Where Site-I showed 53.54% more organic carbon in comparison to control Site.

The phosphrous is a part of every living cell in plant. The every activity of plant such as growth respiration and reproduction depends upon phosphorous levels. Average amount of available phosphorous at Site-I is 108.44±1.28 mg/kg whereas at Site –II there is drastic reduction in available phosphorous content i.e. 23.43±0.44 mg/kg. Site–I contains 362.82% more phosphorous in comparison to control Site. Soil irrigated with sewage water contains higher amount of available phosphorous which play significant role in plant growth [16].

Potassium is the third essential fertilizer element. Potassium is essential for photosynthesis, for protein synthesis, for starch formation and for the translocation of sugars. This is important for grain formation and is absolutely necessary for tuber development. All root crops are generally give response to application of potassium. In present study Site-I showed 121.66±6.23 mg/kg higher amount and Site-II showed 81.66±4.71 mg/kg and thus has relatively lower amount than Site I. where potassium is 48.98% more in Site-I than control Site. Available K content of soil increased significantly by the sewage water application [13].

Ca and Mg are very important elements for plants life. It is the most abundant mineral in soil. These are, however, required in comparatively small amount and are known as secondary nutrients [17]. The Ca and Mg concentration of Site-I were significantly low 2.1±0.1% and 0.09±0.00%, while Site-II showed significantly high concentration 2.75±0.00% and 0.17±0.00%, where Ca decreased by 20.72% at Site-I in comparison to control. The low concentration of Mg decreased by 47.05% at Site –I in comparison to control. The low concentration of Ca and Mg was also observed in sewage water irrigated soil by [18].

It was concluded that there was a decrease in bulk density, electrical conductivity and pH at Site I, which are good for the soil fertility because high bulk density reduces the plant root penetration in soil and high Electrical conductivity and pH also make soil uncomfortable for plant growth so the decrease in these parameters increase ultimately the soil fertility whereas the Ca and Mg decreases at Site-I which are secondary nutrients but the fertility of soil not affected by decreasing these elements.

The increase in temperature and water holding capacity at Site-I also noticed which increased the soil fertility. The increase in Organic C, N, P, K, at Site-I also increase the soil fertility. N,P,K are the most essential plant nutrients which regulates the plant growth and yield of crops so increase in N,P,K, and organic carbon, the fertility of soil at Site-I is more than control Site.

Heavy metal content of the soils

The total heavy metal content of the 0-15 cm top soil from both Sites is indicated in Table 2. The investigations of the total content of heavy metals in the soils was restricted to the top 15 cm since previous studies showed that surface soils are better indicators of metallic burdens. The concentration of heavy metals in wastewater irrigated soil is higher comparatively natural water irrigated soil. The concentrations of heavy metals were presented in Table 2.

The mean concentration of Pb was ranging between 52.72±0.743 in wastewater irrigated soil. The concentration of Pb recorded was comparatively low 8.72±1.91 in the soil irrigated by natural water. Extractable Pb concentration 7.95-23.2 ppm in soil samples irrigated by polluted water of El-Khashab Canal Cairo-Egypt [19]. Similarly the concentration of Pb in 2.94 and 4.18 mg/kg in DTPA extractable sewage irrigated soil of Delhi India [20].

In the present study the mean concentration of Zn was found to be ranging between 264.086±3.0595 in wastewater irrigated soil. The concentration of lead recorded was comparatively low 64.07±3.055 in the soil irrigated by natural water. The concentration of Pb in 1.86 and 10.02 mg/kg in DTPA extractable sewage irrigated soil of Delhi India [21]. Similarly the highest Zn concentration level 52.97 and 94.86 mg/kg in Pump water 2 and 3, respectively, in waste water irrigated soil of Konya-Turkey [22].

In the present observation the mean concentration of copper was found to be ranging between 49.030±2.036 in wastewater irrigated soil. The concentration of Cu recorded was comparatively low 15.696±2.127 in the soil irrigated by natural water. The values of extractable Cu concentration 6.3 – 6.39 ppm in soil samples irrigated by polluted water of El-Khashab Canal Cairo-Egypt [19]. Similarly the concentration of Cu 1.83 and 4.6 mg/kg in DTPA extractable sewage irrigated soil of Delhi India [20].

The mean concentration of Cadmium was found to be ranging between 24.656±1.869 in wastewater irrigated soil. The concentration of Cd recorded was comparatively low 3.323±.5917 in the soil irrigated by natural water. The concentration of Cd in 0.035 and 0.091 mg/kg in DTPA extractable sewage irrigated soil of Delhi India [20]. The extractable Cd concentration 0.19 – 0.26 ppm in soil samples irrigated by polluted water of El-Khashab Canal Cairo-Egypt [19].

Determination of Pollution Index (PI) in soil

It is well known that most of metal and metalloid contamination in the surface environment is associated with a cocktail of contaminants rather than one element. Thus, many workers have used PI of soils and sediment to identify multi-element contamination resulting in the increased overall element toxicity [22,23,24]. Although equations for the calculation of the PI differ among individual researchers, the basic concept of the method is the same. In this study, the PI of each sediment and soil sample was computed by the average ratio of element concentrations in a sample to tolerable levels of soils for plant growth [25]. The equation is as follows: Pi = Ci/Si [Pi is an environmental quality pollution index for a special heavy metal Ci is the heavy metal content in a soil sample (mg kg^{-1});and Si is the permitted standard of the same metal (mg kg^{-1})]. When the PI values exceed 1.0, the soil can be contaminated by anthropogenic inputs and may recommend continuous environmental monitoring of the area. The Pi values of the four heavy metals in both soil are summarized in Table 2. The overall average of Pi value in sewage water irrigated soil was higher than the canal water irrigated soil. The lowest Pi value recorded in canal water irrigated soil for Pb and higher for Zn while the lowest Pi value found in sewage water irrigated soil for Cu and higher in Zn. As a result, Pi values in the samples were calculated to be lower than permissible pollution limit of 1.0.

Determination of Enrichment Factor (EF) in soil

Enrichment factor can be used to assess the contamination degree of heavy metals in the studied soil in more detailed way. To enable a comparison between different geographical areas, EF values are usually normalized with respect to a reference element. The enrichment factor was calculated following the formula [26]:

EF = mean metal concentration of samples/The metal concentration of reference materials., five contamination categories are generally classified on the basis of their enrichment factor as: EF<2

Depletion to minimal enrichment, suggestive of no or minimal pollution, EF=2 –5 moderate enrichment, EF=5 –20 significant enrichment, EF=20– 40 very high enrichment, EF>40 extremely high enrichment (27].

Table 1: Values of physico chemical characteristics of soils from two different Sites of Dehradun city

S. No.	Parameters	Site I (Sewage water)	Site II (Canal water)	Percentile*increase(+) /decrease (-)at Site-I
1	Bulk density (gm/cm^3)	1.26±0.00	1.83±0.00	-31.14 %
2	Water holding capacity	53.60±1.09	41.58±1.41	+28.90 %
3	Temperature (^{0}C)	16.33±1.05	14.50±0.081	+12.92 %
4	Electrical conductivity (dSm^{-1})	0.122±0.00	0.169±0.00	-27.81 %
5	pH	7.50±0.00	7.90±0.00	-5.00 %
6	Organic Carbon (%)	1.95±0.00	1.27±0.04	+53.54 %
7	Avai. phosphorous (mg/kg)	108.44±1.28	23.43±0.44	+362.82 %
8	Avail. potassium (mg/kg)	121.66±6.23	81.66±4.71	+48.92 %
9	Total Nitrogen (%)	2.22±0.57	1.61±0.12	+37.88 %
10	Avail. Calcium (%)	2.18±0.14	2.75±0.49	-20.72 %
11	Avail. Magnesium (%)	0.09±0.00	0.17±0.00	-47.05 %

(All values are Mean±S.E. of 3 observations for each parameter)
**Percentile increase/decrease at Site-I in comparison to control Site (Site-II).*

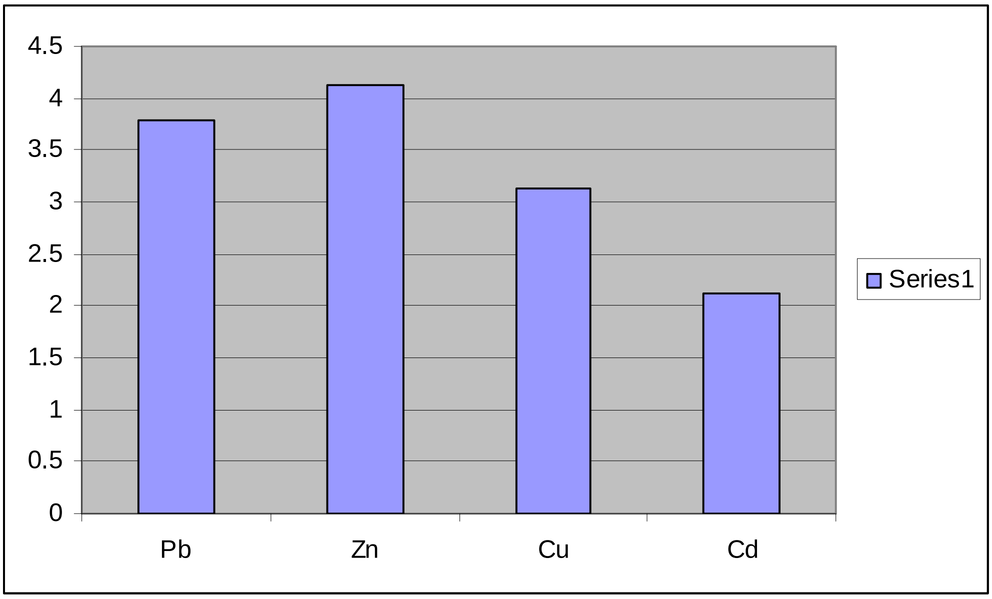

Fig.1. Enrichment of heavy metals in soil

Table-2. Heavy metal concentration (mg kg^{-}1 dry weight) in two different Sites of DehraDun City,India.

Metals	Site-I	Site-II	Percentile increases and decreases	Tolerable limits	Indian standards
Pb	52.72±0.74	13.90±1.56	+279.16	100	250-500
Zn	264.09±3.05	64.07±3.06	+312.18	100	300-600
Cu	49.03±2.03	15.69±2.127	+212.49	300	135-270
Cd	24.66±1.87	11.16±3.27	+120.94	-	3-6

(All values are Mean ±SD. of 3 observations for each parameter)

The EF values for all the metals were in the range of 2.1263658–4.1218464, indicating a range from deficiency to moderate enrichment within the study area.

Table-3: Pollution Index of heavy metals in sewage water and canal water irrigated soil.

Metals	Pi for Site I	Pi for Site II
Pb	0.5272	0.139
Zn	0.880289	0.2135666
Cu	0.4903	0.1569
Cd	-	-

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