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Impact of Irrigation of Industrial Effluents on Soil-Plant Health

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Abstract-With pressure increasing on potable water supplies worldwide, interest in using alternative water supplies including recycled wastewater for irrigation purposes is growing. Wastewater is derived from a number of sources including domestic sewage effluent or municipal wastewater, agricultural (farm effluents) and industrial effluents.[1-5] Although wastewater irrigation has many positive effects like reliable water supply to farmers, better crop yield, pollution reduction of rivers, and other surface water resources, there are problems associated with it such as health risks to irrigators, build-up of chemical pollutants (e.g., heavy metal(loid)s and pesticides) in soils and contamination of groundwater.[6-12]

Growing use of chemicals in agricultural fields and heavy industrialization is responsible for introducing and mobilization of heavy metals into the biosphere. In addition, application of industrial and urban effluents in agricultural fields is responsible for further mobilization of heavy metals into the biosphere and ensuing in a serious threat to the environment and public health. Presence of metal ions such as Zn, Mn, Fe, Cu, Pb, Cd, Ni and Cr in agricultural inputs, especially, sewage sludge, may gradually build up their concentrations in soil. Even the essential nutrients become toxic to plant growth after reaching a certain threshold. Plants may survive under high metal concentrations by sequestering metal ions into their tissues, exposing secondary consumers (human or animals) to the risk of metal toxicity. Heavy metal-polluted soil environments can be reclaimed through the application of chemicals, soil amendments or phytoaccumulators. Out of the three options, phytoremediation is a cost-effective and sustainable method of reclamation of metal-polluted environments. [13-18]

Keywords: *contamination, industrialization, threshold, sequestering, phytoremediation.*

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INTRODUCTION

With increased industrialization in residential areas, different materials are discharged into effluent water which leads to environment pollution. This concern is of special importance where untreated effluent is applied for longer periods to grow vegetables in urban lands. [19-20] such uses are on the increase because the effluent contaminated waste water is a free and good source of organic matter as well as plant food nutrient, variable and cheap option for disposal. As a consequence, the use of waste water and other industrial effluents for irrigating agricultural lands is on the rise particularly in peri-urban areas of developing countries. [21-23]

Long term sustenance of soil fertility of effluent irrigated soils is attributed to the presence of N, P and K in significant quantities in these effluents. Raw sewage and sludge depending upon their source may contain an appreciable amount of metallic micronutrients and heavy toxic metals. Long- term application of these materials to land may cause accumulation of heavy metals in soil and may become toxic to plants. [24] In most of the cities disposal of effluent is carried out by using it for irrigation. This kind of land application of the industrial effluent results in direct addition of trace metals to the soils, resulting in its degradation and also adding of toxic metals in the food chain.[25]

In developed countries industrial effluents are subjected to primary and secondary treatments to separate out the pollutants and bring down the concentration of various toxic elements to safe limits before disposal to the field. However, as far as the municipal waste water is concerned especially in third world nations, usually the treatment is not given. Rather this water is used as a source of irrigation for fodders and vegetable crops grown around the cities.[26] There are however certain methods by which we reduce the concentration of certain metals dissolved in soil. They are classified into two basic types:

1. Chemical Remediation Technique

2. Phyto- Remediation Technique

1. Chemical Remediation Techniques- This involves the addition of some chemical material to polluted soils, in order to reduce the concentration of cadmium and lead dissolved in the soil solution. These chemical materials include the following:

- Lime materials, manure or compost, to increase the soil pH and reduce the solubility of trace elements.
- Iron hydroxides, manganese oxides or zeolite to increase the adsorption sites of trace elements.

- Heavy applications of phosphate to increase the precipitation of metal ions and phosphate ions.

Some reports also indicate that the application of hydrous oxides of iron, manganese or zeolite can reduce the concentration of cadmium or lead dissolved in contaminated soil.[39-44] Heavy applications of phosphate to polluted soils can reduce the amount of zinc dissolved in the soil solution by causing dissolved zinc to precipitate.[27-30]

2. <u>Phyto- Remediation Technique</u> - Some plant species (flowers and trees with a high economic value) can be grown in polluted soils to remove trace elements, and as a way of continuing agricultural production on contaminated soils.[31-32] They are reported as "super-accumulators" of heavy metals and are defined as species which contain more than 0.1% (1,000 mg/kg) of copper, lead, nickel or cobalt in their dried tissues. In the case of zinc, a threshold of 1% (10,000 mg/kg) is proposed.[33-34]

A study has been carried out to access the relative availability of micronutrients and metals in soils irrigated with effluent waters where the practice of irrigating the fields with waste water is being followed by the farmers in the urban fringe area of Raipur City. The present work was undertaken to study the effect of continuous irrigation with effluent water on micronutrients and metal build up in soils and their contents in various crops.

Keeping the above view, a survey of agricultural soils receiving untreated industrial water discharges around Raipur was done and some farmer's field was identified. Mainly vegetable crops are being grown round the year. Paddy is also being cultivated in some portion of the land. Information gathered from the farmers revealed that these untreated water discharges are being used since the last 25-30 years.

The samples of effluent irrigated soils and those of soils which are not receiving industrial effluent discharges were collected and analyzed. The objectives of the present study were to access the impact of long term application of industrial effluent on physio-chemical properties of soil, nutrient and heavy metal accumulation in the soil and crops being grown.

THRESHOLD LEVELS OF TRACE ELEMENTS FOR CROP PRODUCTION

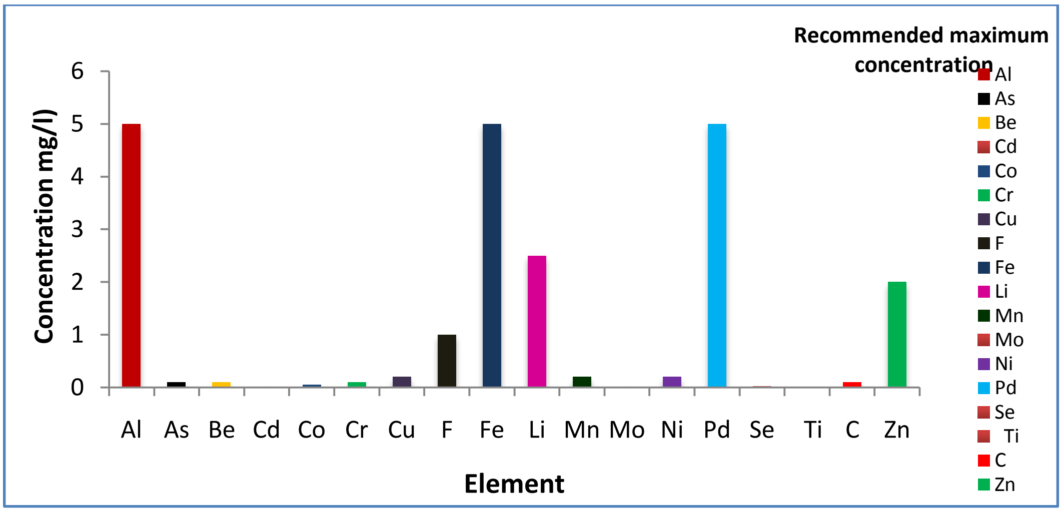
	Element	**Recommended maximum concentration (mg/l)**	**Remarks**
Al	(aluminum)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As	(arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be	(beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd	(cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co	(cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr	(chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu	(copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F	(fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe	(iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li	(lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron
Mn	(manganese)	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Mo	(molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.

Ni	(nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd	(lead)	5.0	Can inhibit plant cell growth at very high concentrations.
Se	(selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. As essential element to animals but in very low concentrations.
Ti	(titanium)	-	Effectively excluded by plants; specific tolerance unknown.
C	(vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn	(zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10 000 m^3 per hectare per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. The values given are for water used on a continuous basis at one site.

Source: Adapted from National Academy of Sciences (1972) and Pratt (1972).

Fig: 1 THRESHOLD LEVELS OF TRACE ELEMENTS FOR CROP PRODUCTION



COLLECTION AND STORAGE OF SAMPLES

1.1 INDUSTRIAL EFFLUENT WATER

The industrial effluent samples were collected from 5 points and the selected sites were marked as site I, II, III, IV and V respectively. Samples collected were stored in clean 2L plastic/ polypropylene bottles for investigations.

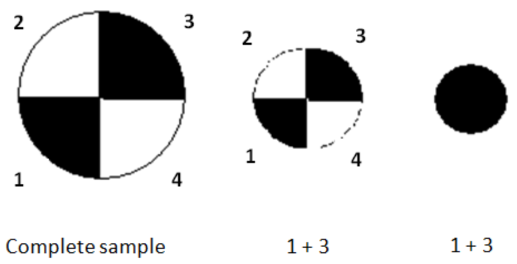
1.2 SOIL

Soil samples were categorized into three classes first which comprised of those soil samples (5 samples) which are continuously receiving industrial effluent discharges second which had those soil samples (5 samples) which are totally unaffected from industrial effluent discharges but are still in the nearby area and third which comprised of those soil samples which are very far i.e approximately 40 Kms away from industrial area.

1.3 SOIL PROFILE

The soil samples whose analysis is to be done are digged from surface to 6 inches deep. If bigger size soil clusters are there then ground them with pestle and mortar and collect, if some amount of moisture is present then air dry the soil samples and pass through 2mm polythene sieve.

Now keeping the soil sample in a circular form divide it into four equal parts and continue separating from two opposite directions until only half kg. soil sample is left and stored in polythene bags for investigations.



Result and Discussion

Table: 1 Physiochemical properties of Industrial Effluent water

Parameters	Site-1	Site-2	Site-3	Site-4	Site-5	Mean	Median	Mode	Std. Deviation
pH	7.5	7.6	7.5	7.3	7.4	7.46	7.5	7.5	0.11
EC (dS m^{-1})	0.70	0.74	0.78	0.79	0.81	0.76	0.78	-	0.04
Cl^- (mg L^{-1})	334	356	348	356	332	345.2	348	356	11.62
SO_4^{2-} (mg L^{-1})	117	132	134	121	124	125.6	124	-	7.23
CO_3^{2-} (mg L^{-1})	44.3	41.2	42.4	43.4	48.9	44.04	43.4	-	2.95
HCO_3^- (mg L^{-1})	266	272	292	298	256	276.8	272	-	17.69
NO_3-N (mg L^{-1})	31.3	33.2	30.8	30.2	29.3	30.96	30.8	-	1.45
NH_4-N (mg L^{-1})	40.1	39.1	37.6	39.3	40.0	39.22	39.3	-	1.00
P (mg L^{-1})	13.1	13.2	12.6	12.4	12.9	12.84	12.9	-	0.33
K (mg L^{-1})	43.2	47.5	43.2	44.6	47.8	45.26	44.6	43.2	2.25
Na^+ (mg L^{-1})	103.5	110.2	112.5	107.9	106.2	108.06	107.9	-	3.48
Ca^+ (mg L^{-1})	56.4	58.9	57.2	51.4	60.8	56.94	57.2	-	3.52
Mg^{++} (mg L^{-1})	21.2	20.9	20.1	18.9	19.3	20.08	20.1	-	0.99
Zn (mg L^{-1})	1.35	1.25	1.56	1.43	1.23	1.38	1.35	-	0.16
Fe (mg L^{-1})	1.56	1.24	1.67	1.73	1.66	1.57	1.66	-	0.19
Mn (mg L^{-1})	0.74	0.98	0.96	1.12	1.07	0.97	0.98	-	0.14
Cu (mg L^{-1})	0.89	0.91	0.87	0.76	0.65	0.81	0.87	-	0.10
Cr (mg L^{-1})	0.35	0.46	0.45	0.39	0.42	0.41	0.42	-	0.04
V (mg L^{-1})	20	63	30	33	40	37.2	33	-	32.23
SAR	4.25	4.35	4.37	4.23	4.40	4.32	4.35	-	0.07

Table: 2. Physiochemical properties of ground water

Parameters	Site-1	Site-2	Site-3	Site-4	Site-5	Mean	Median	Mode	Std. Deviation
pH	6.7	7.1	6.8	6.9	7.1	6.94	6.9	7.1	0.17
EC (dS m^{-1})	0.68	0.72	0.7	0.72	0.69	0.7	0.7	0.72	0.01
Cl^- (mg L^{-1})	242	224	202	212	245	225	224	-	18.62
SO_4^{2-} (mg L^{-1})	96	102	110	98	112	103.6	102	-	7.12
CO_3^{2-} (mg L^{-1})	24.2	32.8	26.9	31.9	28.2	28.8	28.2	-	3.56
HCO_3 (mg L^{-1})	148	202	198	244	214	201.2	202	-	34.77
NO_3-N(mgL^{-1})	21.2	19.6	24.6	20.8	18.9	21.02	20.8	-	2.20
NH_4-N(mgL^{-1})	32.6	29.8	30.2	28.8	34.6	31.2	30.2	-	2.35
P (mg L^{-1})	9.8	8.6	10.2	7.9	10.9	9.48	9.8	-	1.21
K (mg L^{-1})	34.6	42.4	38.2	34.2	40.2	37.92	38.2	-	3.54
Na^+ (mg L^{-1})	96.8	94.9	98.8	104.6	102.2	99.46	98.8	-	3.94
Ca^{2+} (mg L^{-1})	38.8	44.2	46.6	42.5	48.2	44.06	44.2	-	3.66

Mg^{++} (mg L^{-1})	14.8	16.8	18.2	15.6	16.1	16.3	16.1	-	1.28
Zn (mg L^{-1})	1.12	1.08	0.98	1.04	1.08	1.06	1.08	1.08	0.05
Fe (mg L^{-1})	1.04	1.07	1.23	1.2	1.12	1.13	1.12	-	0.08
Mn (mg L^{-1})	0.26	0.42	0.46	0.96	0.98	0.61	0.46	-	0.33
Cu (mg L^{-1})	0.22	0.12	0.32	0.26	0.18	0.22	0.22	-	0.07
Cr (mg L^{-1})	0.11	0.16	0.19	0.11	0.21	0.15	0.16	0.11	0.04
V (mg L^{-1})	12	18	22	24	29	21	22	-	6.40
SAR (me L^{-1})	2.16	2.48	2.98	2.96	2.84	2.68	2.84	-	0.35

Note: Ni, Cd and Pb not detected in all the sites.

The mean, median, mode and standard Deviation of five values of different parameters has been tabulated in Table1 and Table2 namely of Industrial effluent water sample and ground water sample which was collected approximately 40 km away from selected industrial site. The industrial effluent water sample has been symbolized as "IEW" and ground water sample is symbolized as "GWS."

As being shown in the table the pH of IEW sample varied from 7.5 to 7.4 the mean value being 7.46 whereas that of the GWS sample varied from 6.7 to 7.2, mean 6.94. EC values of IEW samples were 0.70 to 0.81 dS $m^{-1,}$ mean 0.76 while that of the GWS samples were ranging from 0.68 to 0.69 and mean was 0.7 dS m^{-1}. SAR values of IEW samples varied from 4.25 to 4.40 with a mean value of 4.32 and for GWS samples these values ranged from 2.16 to 2.84, mean 2.68. All these values were within low range and falls under class C1 and S1 as described by US Salinity laboratory.[1] The Cl^- and SO_4^{2-} for IEW samples varied from 334 to 332 mg L^{-1} and 117 to 124 mg L^{-1} and their mean values being 345.2 and 125.6 mg L^{-1} and that of the GWS samples varied from 242 to 245 mg $L^{-1}$and 96 to 112 mg L^{-1} and its mean came 225 mg L^{-1} and 103.6 mg L^{-1}.

The CO_3^{2-} and HCO_3^- values of IEW samples ranged from 44.3 to 48.9 mg L^{-1} and 266 to 256 mg L^{-1}, mean 44.04 mg L^- and 276.8 mg L^{-1} and for that of the GWS samples these values ranged from 24.2 to 28.2 mg L^{-1}, mean 28.8 mg L^{-1} and 148 to 214 mg L^{-1}, mean 201.2 mg L^{-1}. It was found that these values for IEW samples were quite higher; this must be attributed due to the mixing of residual soaps and detergents. The amount of nitrogen which was namely in the form of NO_3-N and NH_4-N for IEW samples were found to be 31.3 to 29.3 mg L^{-1} and 40.1 to 40.0 mg L^{-1} the mean values being 30.96 and 39.22 mg L^{-1} and for that of the GWS samples these values were ranging from 21.2 to 18.9 mg L^{-1}, mean 21.02 mg L^{-1} and 32.6 mg L^{-1} to 34.6 mg L^{-1}, mean 31.2 mg L^{-1}, all these values were within limits prescribed by CPCB, 1995. The P and K values for IEW samples were 13.1 to 12.9 mg L^{-1} and 43.2 to 47.8 mg L^{-1} mean values being 12.84 and 45.26 mg L^{-1}while for that of the GWS samples these values were ranging from 9.8 to 10.9 mg L^{-1}, mean 9.4 mg L^{-1} and 34.6 to 40.2 mg L^{-1}, mean 37.92 mg L^{-1}. The Na^+, Ca^{2+} and Mg^{2+} values for IEW samples were found to be ranging from 103.5 to 106.2 mg L^{-1} , 56.4 to 60.8 mg L^{-1} and 21.2 to 19.3 mg L^{-1} again mean values being 108.06, 56.94 and 20.08 mg $L^{-1}$for GWS samples these values were 96.8 to 102.2 mg L^{-1}, mean 99.46 mg L^-1, 38.8 to 48.2 mg L^{-1}, mean 44.06 mg L^{-1} and 14.8 to 16.1 mg L^{-1}, mean 16.3 mg L^{-1}.

The mean values of Zn, Fe, Mn, Cu and Cr for IEW samples were found to be 1.38, 1.57, 0.97, 0.81 and 0.41mg L^{-1} respectively as against the limits of 5 mg L^{-1} for Zn, 2.0 mg L^{-1} for Mn, 3 mg L^{-1} for Cu and 2 mg L^{-1} for Cr as prescribed by CPCB (1995)[2] and for that of the GWS samples these values were 1.06, 1.13, 0.61, 0.22 and 0.15 mg L^{-1}. As far as Ni, Cd and Pb are concerned they were not detected in the given samples.

PHYSIOCHEMICAL PROPERTIES OF AGRICULTURAL SOILS IN THE ADJOINING AREAS

Different physiochemical properties of the agricultural soils from the adjoining areas and those areas which were approximately 40 km away from the selected industrial site but was used for agricultural purpose were found out by using standard methods. For this we first categorized soils into three classes first which comprised of those soil samples (5 samples) which are continuously receiving industrial effluent discharges second which had those soil samples (5 samples) which are totally unaffected from industrial effluent discharges but are still in the nearby area and third which comprised of those soil samples which are very far i.e approximately 40 Km away from industrial area.

Table: 3 Soils receiving industrial effluent discharges

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Median	Mode	Std. Deviation
pH	8.4	7.5	7.8	8.4	8.2	8.06	8.2	8.4	0.39
EC(dSm^{-1})	0.52	0.51	0.49	0.48	0.50	0.50	0.5	-	0.01
CEC (me/100g)	21.52	20.19	18.18	17.26	22.12	19.85	20.19	-	2.09
TSS(milli mhos)	0.04	0.06	0.07	0.06	0.05	0.05	0.06	0.06	0.01
OC (Kg ha^{-1})	0.86	0.94	0.96	0.81	0.93	0.90	0.93	-	0.06
N (Kg ha^{-1})	315	302	296	289	256	291.6	296	-	22.07
P (Kg ha^{-1})	10.5	12.4	12.2	11.5	9.3	31.10	11.5	-	1.28
K (Kg ha^{-1})	322	293	256	392	290	310.6	293	-	51.16
Na^+ (me L^{-1})	7.9	8.0	7.8	7.5	7.7	7.78	7.8	-	0.19
Ca^{2+} (me L^{-1})	3.96	3.2	3.6	4.2	4.5	3.89	3.96	-	0.50
Mg^{2+}(me L^{-1})	2.21	2.26	2.3	2.4	2.8	2.39	2.3	-	0.23
Zn (mg Kg^{-1})	4.23	2.10	2.56	3.46	2.87	3.04	2.87	-	0.82
Cu (mg Kg^{-1})	2.10	2.68	3.81	3.99	2.80	3.07	2.8	-	0.79
Fe (mg Kg^{-1})	29.8	23.3	20.	20.9	14.8	21.94	20.9	-	5.46
Mn(mg Kg^{-1})	10.1	18.7	14.2	16.5	15.4	14.98	15.4	-	3.19
Pb (mg Kg^{-1})	1.9	1.78	1.80	1.78	1.98	1.84	1.8	1.78	0.08

Table 4: Soils not receiving Industrial effluent Discharges:

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Median	Mode	Std. Deviation
pH	6.8	6.7	5.8	6.9	6.6	6.56	6.7	-	0.43
EC (dS m^{-1})	0.28	0.26	0.19	0.23	0.28	0.24	0.26	0.28	0.03
CEC (me/100g)	15.12	14.24	13.80	14.24	16.92	14.86	14.24	14.24	1.24
TSS(milli mhos)	0.02	0.03	0.05	0.04	0.04	0.03	0.04	0.04	0.01
OC (Kg ha^{-1})	0.36	0.69	0.78	0.54	0.43	0.56	0.54	-	0.17
N (Kg ha^{-1})	198	210	188	205	196	199.4	198	-	8.47
P (Kg ha^{-1})	10.7	12.6	9.5	11.3	10.3	10.88	10.7	-	1.16
K (Kg ha^{-1})	248	256	212	268	282	253.2	256	-	26.36
Na^+ (me L^{-1})	3.98	4.45	4.36	4.58	4.69	4.41	4.45	-	0.27
Ca^{2+} (me L^{-1})	2.06	2.1	2.04	2.0	2.02	2.04	2.04	-	0.03

Mg^{2+} (me L^{-1})	0.86	0.79	0.94	0.82	0.96	0.87	0.86	-	0.07
Zn (mg Kg^{-1})	1.23	0.62	0.92	0.46	0.78	0.80	0.78	-	0.29
Cu (mg Kg^{-1})	2.54	2.04	2.46	2.20	2.22	2.29	2.22	-	0.20
Fe (mg Kg^{-1})	9.6	12.9	11.1	14.5	10.5	1.72	11.1	-	1.96
Mn (mg Kg^{-1})	7.9	6.8	7.3	7.4	6.4	7.16	7.3	-	0.57
Pb (mg Kg^{-1})	0.04	0.1	0.06	0.05	0.01	0.05	0.05	-	0.03

Table 5: Soils samples of a definite distance from industrial area

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Median	Mode	Std. Deviation
pH	6.9	6.8	6.4	6.9	6.7	6.74	6.8	6.9	0.20
EC (dS m^{-1})	0.18	0.22	0.20	0.24	0.21	0.21	0.21	-	0.02
CEC	11.05	10.54	9.68	9.20	8.74	9.84	9.68	-	0.94
TSS(milli mhos)	0.03	0.02	0.01	0.03	0.04	0.02	0.03	0.03	0.01
OC (Kg ha^{-1})	0.30	0.46	0.42	0.48	0.38	0.40	0.42	-	0.07
N (Kg ha^{-1})	156	182	134	178	162	162.4	162	-	19.20
P (Kg ha^{-1})	9.4	9.8	10.2	8.9	7.8	9.22	9.4	-	0.92
K (Kg ha^{-1})	226	204	210	242	268	230	226	-	25.88
Na^{+} (me L^{-1})	3.42	4.42	3.91	4.22	3.98	3.99	3.98	-	0.37
Ca^{2+} (me L^{-1})	2.01	1.98	1.86	1.78	1.98	1.92	1.98	1.98	0.09
Mg^{2+} (me L^{-1})	0.72	0.46	0.82	0.69	0.68	0.67	0.69	-	0.13
Zn (mg Kg^{-1})	0.94	0.42	0.48	0.38	0.62	0.56	0.48	-	0.22
Cu (mg Kg^{-1})	2.42	2.0	2.28	2.12	2.14	2.19	2.14	-	0.16
Fe (mg Kg^{-1})	8.8	9.8	10.4	12.2	9.6	10.16	9.8	-	1.27
Mn (mg Kg^{-1})	6.8	7.2	6.2	7.4	6.3	6.78	6.8	-	0.53
Pb (mg Kg^{-1})	-	0.01	0.03	-	0.01	0.01	0.01	0.01	0.01

As being discussed earlier the physiochemical properties of different soil samples have been tabulated in Table 3 (Soils receiving industrial effluent discharges) and Table 4 (Soils not receiving industrial effluent discharges) and Table 5 (Soils samples of a definite distance from industrial area). Let us denote it as “SR” For soil samples in Table 3 and “SNR” for soil samples in Table 4 and SDD for soil samples in Table 5.

SOIL PROPERTIES

The pH, EC and TSS values in SR samples were found to be significantly higher than that of SNR and SDD samples. The pH being ranging from 8.4 to 8.2 mean was found to be 8.06 indicating its alkaline nature while in that of SNR samples it was ranging from 6.8 to 6.6 and mean was 6.56 and for SDD samples these values were ranging from 6.9 to 6.7, mean was 6.74.There was also found a marked increase in EC of the SR samples which was ranging from 0.52 to 0.50, mean 0.50 while in SNR and SDD samples its mean was 0.28 and 0.21 which indicates higher amount of salts present in discharges. Similar kind of variation in pH and EC was found by many others.

The TSS contents also of SR samples were found to be about 0.05 milli mhos (mean) while in SNR and SDD it was 0.03 and 0.02 milli mhos. The value of organic carbon in SR was found to be from 0.86 to 0.93 Kg ha^{-1} mean 0.9 Kg ha^{-1} while in SNR it was 0.36 to 0.43, mean 0.56 Kg ha^{-1} and in SDD it was 0.30 to 0.38, mean 0.40 Kg ha^{-1}, this increase in the amount of organic carbon is found to be beneficial for soil health. It is being also reported that increase in organic carbon facilitates the accumulation of available nutrients and metals in the soil.

Conclusion

Important agricultural water quality parameters include a number of specific properties of water that are relevant in relation to the yield and quality crops, maintenance of soil productivity and protection of the environment. These parameters mainly consist of certain physical and chemical characteristics of the water which were systematically studied.

The physiochemical properties of industrial effluent water and ground water samples were systematically analyzed for different parameters namely pH, EC, Cl^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-, NO_3-N, NH_4-N, P, K, Na^+, Ca^{+2},Mg^{2+}, Zn, Fe, Mn, Cu, Cr, V, SAR and it was observed that their amount in the industrial water samples were quite higher than that of the ground water samples which may have considerable impact on the adjoining agricultural soils which are receiving these effluents either directly or indirectly. As we are aware that essential nutrients and trace metals take part in redox reactions and in metabolic functions. Some heavy metals are poisonous and some are highly toxic. These metals are of persistent and bio-accumulative nature and do not break down in the environment easily. The metals being inherent component of uncontaminated soil varying from place to place are limited in amount. The essential trace metals needed by plants and subsequently animals are obtained by soil. The fate of metals would be different in an ideal soil from that which is amended with waste. The concentration of these metals are reported to be 2-7 fold higher in soils receiving industrial effluent discharges as compared to the soils which do not receive these discharges.

Further the soil samples were collected under three categories first which comprised of those soil samples which are continuously receiving industrial effluent discharges (SR) and second which had those soil samples which are totally unaffected from industrial effluent discharges (SNR) but are still in the nearby area and third which comprised of those soil samples which are very far i.e. Approximately 40 Kms away from industrial area (SDD). Again different parameters of these soil samples were studied namely pH, EC, TSS, OC, N, P, K, Na^+, Ca^{2+}, Mg^{2+}, Zn, Cu, Fe, Mn and Pb and it was found that many of these parameters were considerably higher in SR samples than that of the SNR and SDD samples.

But still it would be quite justified to keep in mind that before one can endorse effluent water irrigation as a means of increasing water supply for agriculture, a thorough analysis must be undertaken from an economic perspective as well. In this regard the comprehensive costs and benefits of such wastewater reuse should also be evaluated. Moreover, the economic effects of wastewater irrigation need to be evaluated not only from the social, economic, and ecological standpoint, but also from the sustainable development perspective. The physical and mechanical properties of the soil, such as dispersion of particles, stability of aggregates, soil structure and permeability, are very sensitive to the type of exchangeable ions present in irrigation water. Thus, when effluent use is being planned, several factors related to soil properties must be taken into consideration. The impact of wastewater irrigation on soil may depend on a number of factors such as soil properties, plant characteristics and sources of wastewater.

Possible solutions of problems associated with the sewage and industrial effluents

- To exploit the sewage waters as a potential source of irrigation and maintain environment the sewage waters must be diluted either with canal or underground water to a avoid the excessive accumulation of soluble salts in the soils . It will help in maintaining the productivity of agricultural crop without any harmful effect on soil properties.
- Entry of heavy metals into food chain can be reduced by adopting soil and crop management practices , which immobilize these metals in soils and reduce their uptake by plants .
- Heavy phosphate application and also the application of kaolin / zeolite to soils can reduce the availability of heavy metals.
- Application of organic manures can mitigate the adverse effect of the toxic metals on crops. Thus in the soil contaminated with high amount of toxic metals , application of organic manures is recommended to boost the yield potentials as well as decrease the metal availability to plants.
- Raising hyper accumulator plants (mustard /trees) in toxic metals contaminated soils is recommended to avoid the entry of toxic metal in the food chain.

- The sewage / industrial effluents sludge and the soils must be monitored continuously to avoid the excessive accumulation of toxic metals in the soils and then transfer in the food chain.
- There should be strict government legislation that only those sewage and industrial effluents be used in the fields which are cleaned through sewage and effluent treatment plants.
- Highest priorities should be given to proper disposal of solid and liquid effects from industries for proper land management.

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