Proc. Indian natn. Sci. Acad., **B60**, No. 6, pp. 541-552 (1994)

Possibilities of Using Calcutta Sewage Effluents and Sludges for Irrigation and Manurial Purposes. Part I. Physicochemical Characteristics and Impact of Heavy Metal Contents on Soil and Water

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(Received on 16 May1991; after 2nd revision on 15 May 1992; Accepted on 3 October 1994)

Calcutta sewage effluents and sludges from eight discharge points were assessed in respect of salinity, sodicity, bicarbonate toxicity and micronutrient and heavy metal hazards. The impact of these wastes towards the distribution of heavy metals on soil and ground water have also been studied. Sewage discharges particularly from Chingrighata, Chinatown and Pagladanga have been found to be highly hazardous with respect to salt content, SAR values and chloride concentration. The accumulation of heavy metals (Fe, Cu, Zn, Mn, Pb, Cd, Ni and Co) is being increased in most of the soils fed by raw sewage effluents for years together. The concentration of some of the elements in ground water has also increased to the toxic level. Suitable measures have been suggested in some length to check the pollution.

Key Words: Sewage effluents and sludges, Calcutta city, Physico chemical characteristics, Heavy metals, Impact on soil and water

Introduction

It has been estimated that about 65-70% of the waste water in India does not get any treatment (Kaul et al. 1989). This causes pollution of surface as well as ground waters. Due to lack of treatment and improper mode of disposal, the natural water carry organic matter which is decomposed by micro-organisms, thereby increasing biochemical oxygen demand (BOD) reducing dissolved oxygen (DO) increasing chemical oxygen demand (COD) of water. Although sludges add valuable nutrients and improve physical condition of soils (Kirkham 1975, Hall & Williams 1984) but several studies showed that metals like Cu, Pb, Cd, Cr enter into the food chain through their application in soil and this ultimately causes significant health concern (Bidwell & Dowdy 1987, Totawat 1993). Calcutta sewage effluents and sludges from the standpoint of agricultural purposes have not been assessed so far although a vast area has been fed by sewage effluents and sludges for vegetable production and aquaculture. As a first part, the present investigation aims at studying the physico-chemical characteristics and nutrient

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status so as to assess the quality of Calcutta city effluent and sludge as a source of irrigation and manure and the impact of the heavy metals present therein on soil and ground water.

Materials and Methods

Out of the seventeen drainage pumping stations in the city of Calcutta samples (10 each) were collected from eight discharge points located at eastern namely Ballygunge, Topsia and Palmerbazar and north-eastern fringes (namely Kuliadanga, Pagladanga, Dhapalock, Chinatown and Chingrighata) over a period of time each in monsoon and winter. Sewage effluents from these are mainly domestic in origin except from Chinatown which contain also leather industry waste material in addition to domestic sewage. Sewage (in monsoon and winter) and sludges (in winter) were collected with the help of automatic neutral glass sampler with an in-built thermometer inside the sampler. After the collection, sewage samples were stored in neutral plastic bottles. Sludges were collected in plastic packets. The river Kultigong receives major portion of the Calcutta's sewerage and drainage water through Dry Weather Flow Channel (D.W.F.C.) which is being utilized for the purpose of irrigation and pisciculture. Surface (0-15 cm) and subsurface (15-30 cm) soils (at the intervals of 2 km) and ground water from different depths from different points were collected from the areas fed by D.W.F.C., and analysed for physico chemical and nutrient status.

Immediately after the collection of the samples the following parameters were determined: *p*H & EC (Allen 1974); D.O., B.O.D.& C.O.D. (Trivedy & Goel 1984); cations - Ca, Mg, Na & K and anions -CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, and NH_4-N, NO_3-N and P (Black 1965). Total Fe, Cu, Mn, Zn, Pb, Cd,Cr, Co, Ni in sewage effluents, sludges and sewage-fed soils and water were estimated by Atomic Absorption Spectrophotometer (AAS) after digesting with $HClO_4$ - HNO_3 mixture (Black 1965). D.T.P.A. was used for extracting available micro-nutrient elements and heavy metals from soils and sludges (Lindsay & Norvell 1978). The metals in the extract were estimated by AAS.

Results and Discussion

Physiochemical characteristics of the sewage effluents are presented in table 1. *P*H was neutral to slightly alkaline in most of the cases (i.e. within tolerance limits of 6-9 - U S Salinity Laboratory Staff 1954). During monsoon, EC values in most of the stations were in the medium level(0.89— 2.86 dsm^{-1}), except in Chinatown where it was exceptionally high (15.04) and exceeded the toxic limit as per the United States Salinity Diagram (U.S. Salinity Laboratory Staff 1954). During winter, the value was still higher. The higher EC value in Chinatown in both the seasons is obviously due to the discharge of industrial effluent. The salt content in most of the stations did not very much in both the seasons except at Pagladanga, Chingrighata and Chinatown where it exceeded the critical limit. Dissolved oxygen (D.O.) was undetectable in Ballygunge, Topsia, Dhapalock (during monsoon) in Pagladanga (during winter) and in Chinatown (during both seasons). It varied from 1 to 16 ml/l at other stations.

Na^+ and K^+ concentrations were found to be higher in winter than in the monsoon. This is due to the dilution of these cations in the monsoon. However, except in few cases, the concentration of Ca^{2+} and Mg^{2+} did not decrease in the monsoon which is quite surprising. Although the discharges of these stations are mainly domestic, possibly these localities have some activities which release greater amount of these ions during monsoon than in winter. Among cations, Na^+ was the dominating one in both the seasons followed by Ca^{2+}, Mg^{2+} and K^+. Sodium content for the classification of water is expressed in terms of per cent sodium, defined by

Table 1 *Physiochemical characteristics of sewage effluents**

Location	*p*H	EC (dSm^{-1})	D.O. (ml/l)	BOD mg/l	COD	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO^{2-}_3	HCO^{-}_3	Cl^{-1}	SO^{2-}_4	S.A.R.	T.S.M. (g/l)
								me/l							
Monsoon															
Palmerbazar	7.4	0.89	2.30	112.3	248.0	2.80	2.00	4.13	0.28	-	2.00	4.08	0.52	2.66	0.15
Ballygunge	7.6	1.21	tr	128.0	332.0	2.90	2.70	5.22	0.57	1.00	2.00	5.28	1.08	3.12	0.12
Topsia	7.6	1.41	tr	129.0	324.0	3.40	2.00	5.43	0.42	-	2.05	7.20	1.30	3.30	0.12
Kuliadanga	7.7	1.98	16.00	100.0	224.0	9.90	1.50	6.52	0.44	1.56	1.05	12.48	0.67	2.73	0.16
Pagladanga	7.6	2.88	1.00	123.7	302.0	8.30	4.40	16.52	2.08	0.42	3.00	14.64	1.04	6.55	0.22
Dhapalock	8.0	1.28	tr	127.0	322.0	4.30	2.40	5.43	0.64	0.52	1.05	6.72	1.61	2.96	0.27
Chingrighata	7.7	2.43	3.60	116.4	282.0	11.60	0.20	10.22	0.51	0.30	1.08	14.88	1.87	4.20	0.13
Chinatown	7.6	11.54	tr	130.0	336.0	6.30	5.50	128.26	0.93	1.00	3.05	102.00	13.75	52.80	0.60
Winter															
Palmerbazar	7.3	1.16	10.40	n.d.	n.d.	3.60	2.40	16.30	0.62	-	4.00	5.04	0.08	9.42	0.46
Ballygunge	7.3	1.30	6.00	n.d.	n.d.	4.00	2.20	17.82	0.57	-	6.00	5.28	1.03	10.12	0.08
Topsia	7.5	0.96	10.00	n.d.	n.d.	3.10	2.00	5.86	0.51	-	4.50	9.36	0.11	3.68	0.22
Kuliadanga	7.4	2.52	4.00	n.d.	n.d.	8.00	5.00	14.13	0.72	3.00	3.50	13.68	0.24	5.56	0.06
Pagladanga	7.3	5.88	tr	n.d.	n.d.	7.90	5.60	36.52	2.17	-	5.00	33.60	3.12	14.10	0.18
Dhapalock	7.6	1.25	4.00	n.d.	nd.	4.40	3.90	5.86	0.49	1.00	2.00	5.52	0.19	2.88	0.34
Chingrighata	7.5	4.03	2.40	n.d.	nd.	7.30	5.00	24.34	0.67	1.00	2.00	20.40	1.25	9.85	0.18
Chinatown	8.0	15.04	tr	n.d.	nd.	9.50	4.80	136.95	1.02	-	5.50	103.20	8.96	51.29	0.90

* Average-of ten samples; n.d. - not determined; tr - trace.

Table 2 *Available nutrients and heavy elements in sewage effluents**

Location	NH_4-N	NO_3-N	P	K	Fe	Cu	Mn	Zn	Pb	Cd	Cr	Co	Ni
	ppm				ppb								
Monsoon													
Palmerbazar	19.6	1.5	1.9	11.0	472.0	5.2	4.0	248.2	5.6	tr	tr	tr	tr
Ballygunge	12.6	tr	5.4	23.0	94.0	1.6	7.8	132.0	5.0	tr	tr	tr	tr
Topsia	16.2	4.3	1.1	16.4	142.0	5.2	4.0	134.6	8.8	tr	tr	tr	tr
Kuliadanga	10.6	tr	1.3	17.2	92.0	5.1	1.2	151.8	4.0	tr	tr	tr	2.8
Pagladanga	29.6	2.1	0.8	81.3	182.0	6.7	6.2	202.6	8.5	tr	3.8	4.1	15.8
Dhapalock	8.4	4.4	1.6	25.0	142.6	2.0	2.2	72.4	7.8	tr	tr	tr	tr
Chingrighata	10.3	1.4	0.3	20.0	41.8	2.1	6.6	120.0	11.2	tr	tr	2.4	6.0
Chinatown	115.0	8.9	0.1	36.4	132.0	1.7	2.0	68.0	18.0	0.6	29.6	31.3	58.0
Winter													
Palmerbazar	21.4	tr	3.0	24.2	500.0	5.6	4.4	260.0	6.0	0.9	tr	tr	8.0
Ballygunge	27.0	tr	2.9	22.3	100.0	1.6	8.4	140.0	5.0	tr	1.5	6.0	6.0
Topsia	24.9	18.2	4.2	19.9	150.0	5.6	4.4	140.0	9.0	tr	tr	tr	12.0
Kuliadanga	26.6	tr	2.6	29.7	100.0	5.6	1.4	160.0	4.5	tr	2.0	tr	20.0
Pagladanga	77.3	tr	5.1	84.8	200.0	7.2	7.0	220.0	9.0	2.0	13.0	10.2	36.0
Dhapalock	7.6	8.3	1.3	19.2	150.0	2.4	2.2	80.0	8.0	tr	tr	6.0	16.0
Chingrighata	36.4	tr	1.4	26.2	50.0	2.4	7.2	140.0	12.0	tr	tr	7.0	16.0
Chinatown	156.1	tr	1.0	39.9	150.0	2.0	2.2	80.0	18.0	0.6	29.0	41.0	74.0

*Average of ten samples; tr = trace

$$\%Na = \frac{100 \times Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+}$$

where all the ionic concentrations are expressed in me/l. On this basis, except in Chinatown the percentage of Na was less than 60 and was within the upper permissible limit for irrigation water (IS - 1982). The percentage of Na in the monsoon in Chinatown was nearly 90 indicating high alkali hazards.

The effluents during monsoon had mean BOD values varying from 100 (Kuliadanga) to 130 mg/l (Chinatown) and mean COD values varying from 224 (Kuliadanga) to 335 mg/l (Chinatown). Except in Kuliadanga the values are slightly higher as per IS standards. The highest BOD and COD values in Chinatown are obviously due to the discharge of industrial effluent. It is interesting to note that the total suspended matter was maximum in Chinatown effluent. There was a positive correlation between total suspended matter and BOD (r = 0.378) and COD (r = 0.405).

Sodium absorption ratio (SAR) varied from 2.66 to 52.80 (in monsoon) and 2.88 to 51.29 (in winter). SAR values showed maximum sodium hazards in Chinatown followed by Pagladanga, Ballygunge, Chingrighata and Palmerbazar. In other sampling station, SAR remained within the critical limit (IS - 1982).

CO_3^2 and HCO_3 concentrations of sewage effluents in both the seasons could be rated as marginal and chloride concentration was at toxic level in Chinatown, Pagladanga, Chingrighata and Kuliadanga. Except in Chinatown, SO_4^{2-} concentration was at marginal level in the effluents (IS - 1982). Total suspended matter (TSM) was higher in winter than in the monsoon (with certain exception) and was within the toleable limits (WHO 1984), except in Chinatown. Based on the above results and on the standards given by Bureau of Indian Standards (ISI - 1977) for using the effluents and for discharging them on land for irrigation it may be stated that the sewage effluents from Paglandanga, Chingrighata and Chinatown are highly hazardous followed by Kuliadanga. All other effluents may be used directly or after some minor treatment or after dilution as suggested by WHO (1989). However, the effluents from Pagladanga, Chingrighata and Chinatwon may be used for irrigation by adopting an integrated approach to effluent reuse in irrigation such as wastewater treatment, selection of appropriate crop, soil type, irrigation method etc. The work in this line is in progress.

Macro and Micro-nutrient status and the concentrations of heavy metals in sewage effluents in both the seasons are given in table 2. The concentration of NH_4-N generally ranged from 7.6 to 36.4 ppm (during winter) except Chinatown and Pagladanga where it was 156.1 and 77.3 ppm respectively and 8.4 to 115.0 ppm (during monsoon) NO_3-N was detectable only in. Topsia and Dhapalock in winter; and in monsoon except in Ballygunge and Kuliadanga, it was detected in all other stations - with highest content in Chinatown - however it was within the tolerance limits. The soluble phosphorus in both the seasons was very low-even below the normal ranges whereas-K was rated moderate to high in both the seasons. The concentration of Fe and Zn though very high in both the seasons was within the permissible limits. Cu and Mn were present in small amounts.

The concentrations of Pb (4.18 ppb) and Ni (2.8 - 74.0 ppb), Cd (detected only in Palmerbazar, Pagladanga and Chinatown) and Co (in Ballygunge, Chinatown, Chingrighata, Dhapalock and Pagladanga effluents) were within the critical limit.

The physicochemical characteristics of sludges (table 3) collected from different discharge points revealed: (i) *p*H was neutral to slightly alkaline (ii) EC was highest in Chinatown and lowest in Kuliadange, (iii) organic carbon content was medium to high, (iv) Cation

exchange capacity was maximum in Chinatown (might be due to finer soil particles), (v) Na+ was the dominant cation in exchange complex followed by Ca^2, Mg^2 and K^+, and (vi) except in Pagladanga the base saturation per cent was above 90 in all other cases.

The nutrient status of sludges (table 4) indicated that: (i) the total and available N, P and K were moderate to very high, (ii) Available and total Fe and Zn were the maximum {[in Pagladanga]— available Fe and available Zn levels [in all the sludges - highest in Chingrighata]}, total and available Cu (except in Kuliadanga), and available Mn (in Chinatown and Pagladanga) were at toxic levels. Pb, Cr and Ni were at highly toxic level, while Cd was present either in traces (in Ballygunge and Chingrighata) or at toxic level (other sludges) . However, among the metals, Cr, Fe and Pb pose relatively little hazard to plants and animals as they are converted to a form of very low solubility and unavailability to plants and are mostly accumulated in the surface of the soil (Adhikari et al. 1993). Manganese may constitute a problem when added to acid soils as the increased level of soluble manganese may cause phytotoxicity (Jones & Jarvis 1981). The concentration of Cd was although at toxic level, the phytotoxicity is apparently rare (Chaney & Hornick 1978, Bidwell & Dowdy 1987). Elements like Pb, Cr and Cd are more risky to man and animal than to the crop itself. Kirkham (1975) reported that though the heavy metals constitute a small fraction of the sludges, nevertheless the heavy metal content of soil may be significantly raised through long-term land application of sludges. The study performed by Bansal et al. (1992) in the soil of Jamalpur, Ludhiana indicates that the continous use of industrial waste water for five years or more results in the accumulation of Zn, Cu, Mn and Fe in soil to levels that may cause imbalances of nutrients in the soil and plants and affect adversely the crop yield. Singh et al. (1991) also reported that the contents of heavy metal increased with increasing of irrigation with sewage water as well as refinery effluents. Thus the build-up of heavy metals in soil profile may constitute hazard not only to plants but the consumers of harvested crops. Hinesly et al. (1972) reported that the ratio of concentration in maize leaves to the concentration of grain was about 20:1 for lead, 10:1 for cadmium and chromium and 1:1 for copper and nickel and made a suggestion that a cereal rather than a vegetable crop should be grown in sewage and sludge treated soils because the metals tend to be present in lower concentration in fruits and seeds than in leaves. Arora and Chhibba (1992) reported that in the sewage influenced areas of Ludhiana the soils had lower pH, calcium carbonate and organic carbon contents, while the available Cu was distinctly higher in such soils. In such areas, the concentration of Cu and Fe in wheat leaves were higher while those of Mn and S were lesser but rice leaves had higher concentrations of Zn, Cu, Fe as well as Mn. However, although the sludges of different discharge points of Calcutta city showed toxic level of heavy metals and micro-elements, they raw sewage effluents usually contain low amount of total suspended matter (0.06 to 0.90 g/l) and farmers usually try to avoid use of sludges from raw sewage (field observation).

Post Irrigation Effect of Sewage Affluent on Soil Properties

Impact of sewage irrigated farming on soil properties have been studied in the soils where D.W.F.C. is being used for irrigation. The chemical characteristics of the water of D.W.F.C. have been given in table 5. In general, the effluents of this channel had optimum characteristics having BOD and COD 96 mg/l and 176 mg/l respectively. *p*H, EC and dissolved oxygen were below the toxic limit on the basis of the standaards (ISI - 1977) for using effluents and for discharging them on land for irrigation. Cationic and anionic

Table 3 *Physicochemical characteristics of sludges**

Location	*p*H	EC (dsm^{-1})	Org. C (%)	C.E.C.	Exch. cations				Base saturation (%)
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
					C mol (p^{+}), kg^{-1}				
Palmerbazar	7.1	2.34	1.20	7.7	1.30	0.70	4.56	0.57	92.3
Ballygunge	7.3	2.62	1.83	10.4	2.45	0.85	6.00	0.29	92.1
Topsia	7.1	2.17	1.95	8.9	3.00	0.90	4.07	0.58	95.6
Kuliadanga	7.4	2.11	1.62	10.1	2.75	0.45	5.97	0.43	94.9
Pagladanga	7.7	3.29	2.49	3.7	1.00	0.90	1.07	0.08	82.4
Chingrighata	7.4	2.72	1.71	15.0	6.40	1.35	6.39	0.51	97.9
Chinatown	7.7	10.24	3.21	31.2	9.70	0.60	19.14	0.53	96.0

*Average of ten samples

Table 4 *Nutrient status and distribution of heavy elements in sludges**

Location	Total (%)			Available (ppm)			Total									Available (ppm)								
	N	P	K	N	P	K	Fe	Zn	Cu	Mn	Pb	Cd	Cr	Co	Ni	Fe	Zn	Cu	Mn	Pb	Cd	Cr	Co	Ni
							(%)				ppm													
Palmerbazar	0.34	0.12	0.40	284.1	35.0	287.5	1.47	0.10	0.02	0.02	205.0	4.0	142.5	15.0	300.0	150.0	350.0	4.8	4.6	40.0	2.1	6.9	1.0	72.7
Ballygunge	0.38	0.09	0.36	153.3	32.0	175.0	1.20	0.13	0.01	0.03	140.0	tr	196.3	tr	275.0	150.0	300.0	6.8	7.0	26.2	tr	8.9	tr	88.9
Topsia	0.45	0.13	0.43	385.5	55.0	312.5	1.40	0.13	0.02	0.02	255.0	8.0	240.0	tr	140.0	325.0	380.0	3.2	4.9	54.7	3.8	16.7	tr	33.9
Kuliadanga	0.12	0.13	0.43	184.9	67.0	206.3	1.47	0.13	0.07	0.02	105.0	6.0	43.8	17.5	160.0	125.0	310.0	20.4	5.1	21.7	3.2	2.0	1.8	38.0
Pagladanga	0.47	0.11	0.41	453.2	35.0	181.3	0.87	0.07	0.01	0.01	81.2	3.0	2250.0	17.5	750.0	975.0	300.0	2.0	35.0	19.3	1.3	108.4	1.6	177.3
Chingrighata	0.42	0.12	0.38	304.4	31.6	262.5	2.88	0.38	0.01	0.03	147.5	tr	670.0	22.5	235.0	125.0	560.0	2.4	8.1	28.1	tr	27.6	2.0	68.8
Chinatown	0.46	0.10	0.42	390.0	27.0	437.5	0.60	0.06	0.01	0.02	163.8	5.0	8250.0	30.0	120.0	175.0	160.0	2.4	55.0	31.0	2.2	352.6	2.4	38.8

*Average of ten samples

Table 5 *Physicochemical characteristics of the dry weather flow channel (DWFC)*

*p*H	EC	DO	BOD	COD	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO^{2-}_3	HCO^{-}_3	Cl^{-1}	SO^{2-}_4	SAR	TSM
	(dSm^{-1})	(ml/1)	mg/1		me/1									(g/1)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
7.7	0.97	5.0	96	176	3.3	1.3	6.52	0.55	2.0	0.5	4.08	0.01	4.31	0.12
NH_4-N	NO_3-N	P	K	Fe	Cu	Mn	Zn	Pb	Cd	Cr	Co	Ni		
ppm				ppb										
16	17	18	19	20	21	22	23	24	25	26	27	28		
20.6	tr	1.7	21.5	50.0	2.0	2.2	80.0	7.0	0.2	2.2	8.2	5.0		

Table 6 *Physicochemical characteristics of soils irrigated with sewage water*

Site No.	Depth (cm)	pH	Textural class	EC (dSm^{-1})	Org. C (%)	CEC	Exch. cations				Base saturation (%)	ESP
							Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}		
							$Cmol(p^{+})kg^{-1}$					
S1	0-15	7.8	l	0.93	2.10	12.9	7.99	0.66	1.21	0.89	81.9	9.45
	15-30	7.9	scl	0.41	1.80	11.7	8.40	1.61	0.54	0.32	92.9	4.61
S2	0-15	7.4	l	0.74	2.80	13.3	8.80	1.90	0.22	0.59	86.5	1.65
	15-30	7.6	l	0.51	2.70	14.3	8.79	2.29	0.31	0.22	81.2	2.16
S3	0-15	7.2	cl	2.26	3.10	16.1	10.26	0.12	2.62	0.64	84.7	16.27
	15-30	7.1	cl	2.05	1.80	17.8	11.18	2.52	1.03	0.42	85.1	5.78
S4	0-15	7.3	scl	2.17	1.17	7.0	6.19	0.30	0.12	0.17	96.8	1.71
	15-30	7.3	scl	1.86	1.20	10.9	9.07	0.81	0.17	0.34	95.3	1.56
S5	0-15	7.6	scl	1.67	1.66	9.7	7.47	0.78	0.66	0.18	93.7	6.80
	15-30	7.5	scl	1.61	1.20	11.5	8.53	1.32	1.07	0.11	95.9	9.30

ESP - Exchangeable sodium per cent; l - loam; cl - clay loam; scl - sandy clay loam

Table 7 *Nutrient status and distribution of heavy elements in soils irrigated with sewage water*

Site No	Depth (cm)	Total (%)			Available (ppm)			Total									Available (ppm)								
		N	P	K	N	P	K	Fe (%)	Zn (%)	Cu ppm	Mn	Pb	Cd	Cr	Co	Ni	Fe	Cu	Mn	Zn	Pb	Cd	Cr	Co	Ni
S1	0-15	0.18	0.20	0.05	171.0	165.0	100.0	1.60	0.13	160.0	160.0	170.0	4.0	126.3	25.5	600.0	37.5	36.0	3.9	93.0	63.6	0.78	13.1	1.5	103.1
	15-30	0.09	0.15	0.04	204.0	150.0	75.0	1.45	0.13	168.0	140.0	172.3	5.0	100.5	22.5	100.0	45.0	42.0	1.8	69.0	64.4	0.97	9.1	2.4	23.7
S2	0-15	0.32	0.18	0.05	164.1	160.0	180.0	2.20	0.13	160.0	160.0	140.0	4.0	96.6	24.0	190.0	75.0	66.0	4.3	180.0	55.6	0.80	6.3	3.0	32.3
	15-30	0.29	0.15	0.05	194.1	135.0	145.7	1.35	0.13	171.0	200.0	180.0	3.0	122.5	20.0	140.0	60.0	54.0	2.9	150.0	70.2	0.61	8.6	2.7	32.2
S3	0-15	0.26	0.23	0.06	236.9	167.5	190.0	1.90	0.15	166.0	220.0	181.0	4.3	120.0	27.6	520.0	67.5	66.0	22.5	156.0	70.6	0.76	13.8	2.3	88.4
	15-30	0.19	0.19	0.06	223.7	167.5	140.0	1.85	0.14	165.0	180.0	179.0	5.4	113.6	23.7	210.0	142.5	66.0	28.5	171.0	69.8	1.08	13.0	2.1	48.3
S4	0-15	0.22	0.13	0.05	151.3	95.0	85.0	1.85	0.10	131.0	140.0	175.0	3.9	118.0	28.5	325.0	165.0	42.0	7.5	180.0	31.5	0.78	22.3	1.8	55.2
	15-30	0.19	0.12	0.04	164.5	87.5	90.0	1.70	0.08	400.0	120.0	176.0	4.9	124.5	23.6	120.0	60.0	90.0	16.5	171.0	31.7	0.91	12.8	1.8	27.6
S5	0-15	0.29	0.24	0.04	151.3	167.5	60.0	1.55	0.10	144.0	120.0	180.0	4.2	127.5	35.0	720.0	67.5	48.0	12.0	93.0	34.6	0.86	15.7	3.0	122.4
	15-30	0.24	0.26	0.05	190.8	190.0	105.0	1.70	0.09	140.0	100.0	146.3	5.1	102.5	25.5	100.0	60.0	54.0	9.0	108.0	26.8	1.01	16.0	2.8	21.2

Table 8 *Chemical composition of ground water of sewage fed areas*

Sample	*p*H	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO^{2-}_3	HCO^{-}_3	Cl^{-}	SO^{2-}_4	SAR	Fe	Cu	Zn	Mn
		(dSm^{-1})	me/l									ppm			
I (70ft)	8.0	4.99	14.2	7.3	23.5	0.05	1.29	6.23	29.0	tr	7.16	0.80	0.024	0.80	0.96
II (60ft)	7.8	2.82	11.2	4.9	15.6	0.04	0.86	5.16	17.5	tr	5.51	0.80	0.032	1.60	1.44
III (70ft)	8.0	5.14	16.0	4.0	27.4	0.04	1.07	6.45	33.6	tr	8.65	2.00	0.040	1.60	1.12
IV (100ft)	8.2	2.48	10.3	0.8	20.9	0.05	1.08	5.16	14.9	tr	8.87	0.80	0.032	0.80	0.64
V (120ft)	8.0	5.20	11.1	6.0	35.7	0.04	1.50	6.02	32.6	tr	12.21	1.20	0.040	4.16	0.56

concentrations were within the permissible limits specified by FAO (1985).

The sewage irrigated soils were neutral to slightly alkaline in reaction pH ranged from 7.1 to 7.9 (table 6). EC values were low to moderate level. Organic carbon content was quite high. In most of the cases, surface soil contained more organic carbon than the sub-surface soil. Variation in exchange capacities in soils of different points might be due to differential content of organic matter and clay content. Ca^{2+} was the dominant cation in the exchange complex. ESP remained below critical level.

Among the macro-nutrients, total N and P could be rated as medium to high (table 7) while K low to medium. Available N, P and K were observed at high level. Subsurface soils generally contained higher amount of available N while surface soils contained higher amount of P and K. Similar observations were made by King (1982).

The content of total Fe and Zn in sewage irrigated soils (table 7) were found to be exceptionally high. Cu and Mn were also at toxic level. It was also found that, in general, the surface soil contained higher amount of total Fe, Zn and Mn but in case of Cu the reverse was the case. The concentration of Pb, Cd and Ni was found higher than the normal range as proposed by NAS (1974), CAST (1976) and WHO (1989). The contents of Cr and Co were also at higher level. Interestingly enough the heavy metals constituted only a minor fraction of the sewage and sludge but their contents in soils were much higher because of long term application of sewage and sludge. However, Narwal et al. (1991) observed that Ni, Zn, Mn, Fe and Cu concentrations of plant tissue were not increased to toxic levels in soil which was irrigated with sewage water continously for eight years.

Among the DTPA extractable micro-nutrients Fe and Zn were quite prominent. Concentration of Fe, Cu, Mn and Zn varied from 37.5 to 165, 36 to 90, 1.8 to 28.5 and 69 to 180 ppm respectively. All the metals including the heavy elements were found at toxic level (NAS 1974, CAST 1976).

Effect of Sewage Effluent on Ground Water

The chemical composition of ground water of ground water of sewage fed area has been presented in table 8. *p*H of the water of different depths was alkaline in reaction but within the tolerance limit both for drinking and irrigation purposes (ISI - 1977). On the basis of electrical conductivity, the ground water of all the five points may be classified as excellent quality water for irrigation. Ca^{2+} was the common constituent present in natural water. As per WHO and ISI standard for drinking water and irrigation water, the concentrations of Ca^{2+} and Mg^{2+} were within the desirable limits. Both the bicarbonate and carbonate concentrations of ground water could be rated as marginal. The concentrations of chloride ion varied from 14.9 to 33.6 me/l and was at toxic level for cereal crops.

The ICMR (1975) fixed the desirable limit of iron concentration in potable water at 0.1 ppm and the maximum permissible limit at 1.0 ppm. On this basis, the ground water except in III and V was suitable for drinking purpose but for irrigation purpose the ground water of all the points wasnot harmful. The concentration of Cu and Zn was within the tolerance limit for drinking and irrigation purposes (ISI 1977). But so far as Mn is concerned, the water should not be used for drinking purpose. However, for irrigation Mn had no harmful effect. Heavy metals were not at all detected in the ground water.

From the foregoing it is evident that although sewage effluents and sludges are being applied to agricultural land for irrigation and manure they contain heavy metals and other toxic compounds. These heavy metals are accumulated in soils by adsorption or precipitation phenomena and their concentrations in soils may be increased significantly through the long-term land

application. Some are essential for plants in small quantities but their concentrations above optimum level become harmful to plants and animals. Generally, the average application rate of waste water per unit area is in excess of the normally allowable application rates in any properly managed irrigation system. Hence the waste water should be used judiciously in agriculture. Heavy metals are best removed at the source of generation rather than after mixing with other wastes. Solid wastes and debris are also best handled by being prevented from throwing into the water body. Moreover, dilution of these waste water with fresh water can be adopted wherever feasible to decrease the concentration of heavy metals and other toxic substances. Land disposal of solid wastes should be under strictly regulated condition taking all aspects of the characteristics of the pollutants, site of disposal mode of disposal, storage etc. It is true that there are many constraints, economical, social as well as practical in the implementation of the remedial measures suggested above but considering the high manurial values and beneficial effect on soils as also an alternate resources of water for agriculture, the land treatment of waste water provides an alternate source of water for irrigation, for the production of food, fodder, fibre and fuel.

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