IMPACT OF EFFLUENT CHANNEL ON GROUND WATER QUALITY AND, METAL CONTENT IN THE SOIL ALONG THE CHANNEL AND IN THE SEDIMENT AT THE MAHI ESTUARY AT THE GULF OF CAMBAY.

CHAPTER - II

IMPACT OF EFFLUENT CHANNEL ON GROUND WATER QUALITY AND, METAL CONTENT IN THE SOIL ALONG THE CHANNEL AND IN THE SEDIMENT AT THE MAHI ESTUARY AT THE GULF OF CAMBAY

Continuous and steady discharge of industrial effluents either on land or into the water bodies (rivers and estuaries) can have long term repercussions in the form of deposition of pollutants in the sediment in the top and bottom layers of soil and, possible percolation into the underground aquifers. On a futuristic basis, this can not only suffocate but also contaminate well waters. The Baroda effluent channel, 56km long Asia's first and India's only one of its kind, was commissioned with the express purpose of discharging the industrial waste of the Nandesari and Koyali Complex into the Mahi estuary at the Gulf of Cambay, after treatment in a common plant. This was a measure aimed at reducing the pollution load on the already polluted Mahi and Mini rivers. The channel discharges at an average 32 M.G.D (Millions Gallons per Day) of industrial effluent into the Mahi estuary at the Gulf of Cambay for the last 12 years. The channel is covered all along its route, by movable R.C.C. slabs. The villages of Baroda and Bharuch districts through which the channel passes, have water scarcity for irrigation purpose, during most part of the year other than the monsoon months. The channel with its movable R.C.C. slab covers, has proved as a blessing in disguise for the villagers residing along it as, they draw water from the channel for irrigating their fields. Due to frequent break down of the treatment plants or literal non-operation for most of the time, the channel discharge is rich in pollutants of various kinds. This was revealed by the previous studies carried out on the physico-chemical characteristics and metal contents of the channel water as well as the estuarine water (Chapter -I).

This scenario predilects the potential of heavy metal sedimentation and, soil deposition of pollutants on a cumulative basis. Further, as the agricultural lands are flanked on one side by the channel from which water is pumped into these fields and, the Mini river on the other side, which is highly polluted and unsuitable for animal life and human consumption, there is every possibility of contamination of the ground water and consequently of the wells in that area by underground seepage and movement into aquifers. To assess the ecological implications, an analysis of the estuarine sediments and, soil samples along the channel and well water in the villages, for pollutants, becomes pertinent. Since no such eco-analysis has been made so far from the time the channel was built, an attempt is made on these lines to screen metals and specific pollutants, as presence of metals in adequate amount has been seen previously both in the effluent discharge and estuarine water.

MATERIALS AND METHODS

The soil and sediment analysis was carried out by collecting samples of soil from 55 points on either side along the channel (every 01 km) and, 5 samples of sediment from the estuary, one afrom the J-point (the region of confluence), two from upstream of the J-point, and two from downstream of the J-Point. For ease and convenience of handling the data, values of soil metal content obtained for every 11 km have been pooled together and average value calculated. The data is thereby presented under 5-sampling heads from the channel. similarly, the values of sediment metal content obtained from the two upstream points and the two downstream points have been clubbed together and the average value calculated so as to form one upstream data and one downstream data. The entire study was carried out in 1992 and samples of soil and sediment were collected twice from every point. For analysis of underground water quality, water samples from 23 wells along the channel falling under different villages and situated about 50 meters at an average from the effluent irrigated soil, were collected during 1992. Whereas soil samples were collected from both sides of the channel, water samples were collected from the wells on the right side only where the irrigational activity is maximum. As control, to understand the background level of metals in the area, soil samples were collected from a distance of 150-200 meters to the left of the channel which was not contaminated with the channel water. Background levels & various parameters of water were studied by using samples of well water obtained from different parts of Baroda and Panchmahal districts. Soil/sediment samples were collected by Auger method from a depth of 1.75 meters and the column of soil collected was divided into three blocks of approximately 60 cms each. These were distinguished as top, middle and bottom layers of surface soil. Water was collected (grab sampling) and analysed for the metals and other physico-chemical parameters. For the analysis of metals in soil and sediment, samples were dried in the laboratory at room temperature and finally ground to powder. One gm sample was taken in conical flask and 3 ml each of concentrated HNO3 and H_2SO_4 were added and the volume was made to 100ml with distilled water. The flasks were then kept for digestion on a hot plate till the volume shrank to 5ml. The volume was remade to 100 ml again with distilled water and filtered through Whatman filter paper no 40. Ten ml from this was taken and made to 100ml, with distilled water. Metals were extracted by using methyl isobutyl ketone and later on subjected to aspiration in an atomic absorption spectrophotometer. Same procedure was followed for blank.

The values are expressed as mg/kg. The metal content of water samples was analysed as per the method described in chapter-I. Physico-chemical parameters of the well water were also analysed as per the methods described in chapter-I.

RESULTS

SEDIMENT

The metal content of the three layers of the sediment is shown in table 1.

1. In general, the metal content showed progressive increase from top to bottom layers. Of the metals studied, the lowest content was of Cd & Cu & the maximum content was that of Zn. .paThe other metals having values ranging between these two extremes were Ni, Cr, Pb & Fe, in increasing order. Compared to the J-Point, the upstream area showed higher content of all metals and the downstream area had lower content. The average metal content (mg/kg) at the J-point was 300 for Cd & Cu, 500 for Ni, 600 for Cr & Pb, 1000 for Fe & 2000 for Zn. The upstream content of these metals was 300 for Cd & Cu, 657 for Ni and Cr, 800 for Pb, 100 for Fe and 3000 for Zn. The downstream content was 100 for Cd, 200 for Cu and Ni, 300 for Cr, 400 for Pb, 300 for Fe and 500 for Zn.

TABLE 1 : METAL CONTENT IN THE SEDIMENT AT THE "J" POINT (J), DOWNSTREAM (D) AND UPSTREAM (U) OF MAHI ESTUARY

			UPSTREAM	J-POINT	DOWNSTREM
SR.NO	METAL	TYPE	1	2	3
		T	1.5838	0.9821	0.3168
1	Fe	M	1.66657	1.0099	0.34015
		B	1.778	1.0389	0.36485
		T	3.105	1.986	0.576
2	Zn	M	3.01	2.11	0.592
		B	3.229	2.554	0.617
		T	0.327	0.299	0.2
3	Cu	M	0.338	0.332	0.206
		B	0.394	0.413	0.212
		T	0.579	0.504	0.189
4	Ni	M	0.618	0.512	0.201
		B	0.627	0.589	0.212
		T	0.657	0.614	0.31
5	Cr	M	0.675	0.652	0.317
		B	0.747	0.699	0.388
		T	0.327	0.299	0.104
6	Cd	M	0.357	0.302	0.126
		B	0.371	0.311	0.138
		T	0.858	0.679	0.433
7	Pb	M	0.877	0.689	0.437
		B	0.882	0.69	0.442

T – Top layer of sediment
M – Middle layer of sediment
B – Bottom layer of sediment
Unit – mg/g

SOIL

All the metals analysed showed increase in concentration from top to bottom layers. The content of all metals showed steady increase form 100 to 500 mg/kg down the channel. The back ground metal content of control soil samples expressed as mg/kg was 1.0 for Ni, Cu and Cr, 2.0 for Cd, 3.0 for Pb, 2.0 for Zn and 0.3 for Fe. The minimum and maximum content mg/kg along the channel were - 100 to 400 for Ni, 100 to 200 for Cu, 100 to 400 for Cr, 100 to 200 for Cd, 500 to 900 for Pb, 700 to 800 for Fe and 1000 to 2000 for Zn. The data on the metal content of the soil samples is given in table 2.

WELL WATERS

The various parameters evaluated showed that the well waters in the vicinity of the channel had significant contamination as .pacompared to the wells in other areas. The values of various physico-chemical parameters and metal content are shown in tables 3 and 4. The physico-chemical parameters which have shown significant changes are total solids (TS), total dissolved solids (TDS), COD, BOD, Cl^- and So_4 content, Nitrate Content, alkalinity and, all metals analysed. i.e, Cu, Cr, Ni, Zn, Pb, Fe & Cd. The range of various physico-chemical parameters in the control well-

TABLE 2: METAL CONTENT IN THE CHANNEL IRRIGATED SOIL (RIGHT SIDE OF THE CHANNEL- POINT 1-5) AND NON IRRIGATED SOIL (LEFT SIDE OF CHANNEL- POINT 1-5)

SR.NO	METAL	TYPE		1	2	3	4	5
1	Fe	T	C	0 3215	0.2893	0 2651	0.3001	0.3101
			P	0 7023	0 7581	0.8235	0.8821	0 7861
		M	C	0.2986	0 2071	0 2033	0.2865	0 2733
			P	0 7121	0.7691	0.8332	0.8993	0 7999
		B	C	0.2500	0 1917	0 1869	0 1926	0 1599
			P	0.7232	0.7791	0.8521	0.9001	0.8115
2	Zn	T	C	0.00445	0.00250	0.00144	0.0022	0 00157
			P	1.0684	1.618	1.592	1.735	1.903
		M	C	0.00236	0 0015	0.00111	0.00137	0.0015
			P	0.9713	1.644	1.611	1.7622	2.005
		B	C	0.00180	0.00267	0.001	0.0012	0.001
			P	1.1021	1.698	1.697	1.919	2.058
3	Cu	T	C	0.00154	0.00120	0.00137	0.001	0.00133
			P	0.1051	0.1538	0.1529	0.1702	0.2444
		M	C	0.001	0.0114	0.00125	0.001	0.001
			P	0.1058	0.1575	0.1498	0.1744	0.2474
		B	C	0.001	0.001	0.001	0.001	0.001
			P	0.109	0 1646	0.1557	0.1814	0.2569
4	Ni	T	C	0.001	0.00166	0.00175	0.00112	0.001
			P	0.1033	0.1215	0.1367	0.1636	0.4514
		M	C	0.001	0.001	0.001	0.001	0.001
			P	0.1046	0 1235	0.141	0.1726	0.4653
		B	C	0.001	0.001	0.001	0.0017	0.001
			P	0.11	0.1288	0.1484	0.1882	0.4873
5	Cr	T	C	0.00136	0.00133	0.001	0.001	0.001
			P	0.11036	0.1252	0.1421	0.1403	0.4703
		M	C	0.0014	0.001	0.001	0.001	0.001
			P	0.11136	0.129	0.1456	0.1951	0.4599
		B	C	0.001	0.001	0.001	0.001	0.001
			P	0.11354	0 1354	0.1492	0.1999	0.4666
6	Cd	T	C	0.00218	0 00291	0.00201	0.00296	0.00287
			P	0.1321	0 1561	0.1629	0 1633	0.2002
		M	C	0 00198	0.00207	0.00198	0 00216	0.00210
			P	0.1511	0.1621	0.1933	0 1741	0.2082
		B	C	0.00175	0.00183	0.00147	0.00189	0.00163
			P	0.1728	0.1937	0.2001	0.1994	0.2253
7	Pb	T	C	0.00318	0.00244	0.00125	0.0025	0.00133
			P	0.5838	0.7624	0.6221	0.7635	0.7723
		M	C	0 00212	0.00142	0.001	0 001	0.001
			P	0 5902	0 7874	0.6339	0 7714	0 8501
		B	C	0 0015	0 002	0 001	0.001	0 001
			P	0 5948	0 8134	0 6724	0 7871	0.9141

T - Top layer of soil
M - Middle layer of soil
B - Bottom layer of soil
(Unit - mg/g)

C - Control soil (Non - channel irrigated)
P - Polluted soil (channel effluent irrigated)

TABLE 3: SHOWING PHYSICO-CHEMICAL PARAMETERS IN WELL WATERS FROM NON CHANNEL AREA (unit- mg/l)

SR. NO.	TEMPERTURE °C	pH	TS	TDS	SS	DO	COD	BOD	CI	SO4	NO_3-N	ALK.	HD.
1	28	7.1	111	107	4	6.8	11	0.9	13	8	-	160	279
2	29	6.8	106	78	8	5.9	7	1.1	24	12	3	137	141
3	27	6.9	87	77	10	7	13	1.2	17	14	-	210	110
4	29	7	99	87	12	6.9	9	0.79	13	22	-	210	109
5	29	7	115	111	4	6.7	12	0.73	24	9	-	179	210
6	27	7.2	168	160	8	7	13	0.5	25	37	1.7	168	121
7	28	7.1	237	219	18	6.9	9	1	41	23	2	121	246
8	29	6.9	239	231	8	7.3	12	0.7	27	11	-	111	213
9	28	6.9	103	99	4	7.3	11	0.75	17	9	-	140	107
10	27	6.8	173	161	12	6.9	13	0.9	23	50	2	131	101

ALK : ALKALINITY
HD : HARDNESS

TABLE 3 : SHOWING METALS CONTENT IN NON POLLUTED WELLS

	METALS						
SR.NO.	Cu	Cr	Ni	Zn	Pb	Fe	Cd
1	0.001	0.001	0.001	0.001	0.003	0.002	0.001
2	0.001	0.002	0.001	0.001	0.002	0.005	0.001
3	0.002	0.001	0.001	0.003	0.004	0.006	0.002
4	0.001	0.001	0.001	0.003	0.003	0.005	0.001
5	0.003	0.002	0.001	0.005	0.007	0.007	0.001
6	0.002	0.001	0.001	0.006	0.005	0.007	0.001
7	0.002	0.001	0.001	0.007	0.009	0.007	0.002
8	0.003	0.001	0.002	0.004	0.003	0.010	0.001
9	0.003	0.001	0.001	0.007	0.009	0.090	0.002
10	0.002	0.001	0.001	0.007	0.006	0.010	0.001

(UNIT - ug/l)

TABLE 4: SHOWING PHYSICO-CHEMICAL PARAMETERS IN POLLUTED WELLS

(unit - mg/l)

SR.NO	TEMPERATURE °C	pH	TS	TDS	SS	DO	COD	BOD	CI	SO4	NO3-N	ALK	HARDNESS
1	29	6.9	472	460	12	6.2	20	1.3	170	37	15	670	260
2	30	7.1	534	527	7	5.9	27	1.7	173	24	11	320	116
3	38	7.2	630	620	10	7	47	2	400	20	14	78	47
4	31	7	548	533	15	6.3	20	2.2	202	26	12	112	80
5	30	6.9	493	480	13	6.7	17	1.3	186	19	12	88	193
6	29	6.9	334	327	7	6.9	20	2.1	103	17	0.2	107	68
7	30	7	602	590	12	7	20	1.7	209	27	1.1	88	60
8	29	6.9	675	666	9	6.8	17	1.9	137	12	0.3	130	58
9	29	7.3	638	627	11	6.8	17	1.7	413	17	1.1	77	92
10	29	7.4	605	593	12	6.1	20	2.2	389	28	20	160	80
11	27	6.2	737	727	10	5.3	29	2.1	197	80	700	80	67
12	29	6.4	444	437	7	5.9	14	2.2	298	27	17	111	88
13	30	6.9	430	422	8	6.2	17	1.4	97	13	12	90	103
14	29	7.2	426	419	7	7	33	1.9	88	18	11	213	69
15	28	6.3	460	451	9	6.7	7	2.3	76	24	7	141	57
16	30	6.9	629	617	12	8.1	12	2.4	169	145	6	98	87
17	27	7.2	2212	2200	12	7.9	19	2.4	1100	219	4	161	67
18	27	7.3	3081	3071	10	6.9	11	2.7	1768	37	2	99	110
19	39	7.1	2108	2091	17	7.3	42	2.7	1499	83	10	103	213
20	38	7.3	525	513	12	7.4	11	2.9	230	29	11	17	90
21	29	7	411	400	11	7.2	20	2.2	90	30	11	103	78
22	30	6.9	607	600	7	7.2	24	1.7	110	58	11	330	97
23	29	7.2	729	717	12	6.9	20	1.9	130	58	12	297	111

TABLE 4 : SHOWING METALS IN POLLUTED WELLS

SR.NO.	Cu	Cr	Ni	Zn	Pb	Fe	Cd
1	10	11	7	13	16	8	13
2	9	8	3	17	17	120	7
3	27	5	6	33	21	80	9
4	11	7	8	21	19	60	8
5	11	9	8	22	11	17	9
6	7	11	7	37	23	11	7
7	7	11	8	19	17	13	5
8	5	7	4	11	9	13	3
9	11	5	8	13	20	11	7
10	12	11	10	21	17	33	8
11	17	22	13	37	43	82	17
12	13	17	8	22	32	50	9
13	12	16	7	25	34	37	17
14	9	13	6	27	27	66	13
15	8	9	5	23	27	68	8
16	7	11	5	20	30	44	12
17	6	13	5	32	28	48	7
18	3	2	9	28	27	37	9
19	2	3	7	13	23	17	8
20	11	9	12	11	11	12	8
21	10	11	10	9	12	17	10
22	11	23	11	23	30	12	13
23	13	16	17	33	22	13	9

(UNIT - ug/l)

waters was, TS- 87 to 293 mg/l, COD- 7 to 13 mg/l, BOD-Nil, Cl- 13 to 41 mg/l, So_4- 8 to 50 mg/l, Nitrate- 1.7 to 3.0 mg/l and alkalinity- 111 to 210 mg/l. The corresponding values for the well waters adjacent to the channel were, TS - 41 to 3081 mg/l, COD-7 to 47 mg/l, BOD- 1.3 to 2.9 mg/l, Cl^-- 76 to 1768 mg/l, So_4 -12 to 219 mg/l, Nitrate 0.3 to 700 mg/l and alkalinity 77 to 670 mg/l. The metal content of control well waters ranged between 0.001 to 0.003 mg/l for Cu, 0.001 to 0.002 mg/l for Cr, 0.001 mg/l for Ni, 0.001 to 0.007 mg/l for Zn, 0.002 to 0.009 mg/l for Pb, 0.001 to 0.002 mg/l for Cd and 0.002 to 0.01 mg/l for Fe. The corresponding values for the channel adjacent well waters were 0.002-0.027 mg/l for Cu, 0.002 to 0.022 mg/l for Cr, 0.003 to 0.017 for Ni, 0.009 to 0.037 for Zn, 0.009 to 0.043 for Pb, 0.014 to 0.059 for Cd and 0.008 to 0.120 for Fe.

DISCUSSION

The present study shows that the estuarine sediment has very high level of Zn, high levels of Fe and Pb, and moderately high levels of Cr and Ni, and low levels of Cu and Cd. A significant feature of the observations is the relatively higher levels of all the metals studied in the upstream area compared to the J-point. Interestingly, the downstream area depicted lower levels. It is generally known that oceanic sediment are richer in metal content than the riverine sediment due to flush down by river and from atmospheric fall out (Zhang *et al.*, 1992). However, the present observation of higher metal content in the upstream sediment than the downstream sediment, contravenes this concept. Two reasons that could be ascribed to this peculiar aspect in the Mahi estuary are :

1. That the construction of a dam upstream on the river at Kadana, has totally hampered the flushing ability of the river and consequently, the tidal ingress carries back the effluent metallic contaminants from the J-point to the upstream areas.

2. That there is unchecked dumping of untreated industrial effluents into the river Mini, a tributary of Mahi, which confluences with Mahi about 25 Km upstream from the J-point. In keeping with the previous observations of consistent increase of pollutants in the effluents discharged through the effluent channel over the years, it is predictable that the metallic content of the Mahi estuary sediment would increase further over the years.

The influence of the increasing metal content and even other pollutants, on the estuarian ecosystem and its biotic forms, is difficult to predict. However, the drastically reduced population of fishes and crustaceans, observed during the course of the present study, as well as ascertained by the recounting by the fishermen and villagers (which were recorded in higher numbers about 10 years ago), stands testimony to the obvious consequences. The increasing metal content in the sediment may have many devious and complicated interactions leading to long term problems in the area, which are not fore-seeable. There is every possibility that the benthic population may be drastically altered. Alternatively, biochemical decomposition leading to release of noxious materials or even conversion to more biologically hazardous forms are also possible. Both biotic and abiotic factors can influence the chemical forms the metals may take or even the amount of dissolved metals and metal adsorption potential of the aquatic system (Wittman, 1981). The fate of metals in aquatic systems depends on the metals being considered, pH of the system, redox-potential, soil composition and availability of chelating agents (Jennett *et al.*, 1980, Chan *et al.*, 1982). Reduced alkalinity of water can promote bio-availability of metals and, in this context, the reducing trend of alkalinity in the Mahi estuarine system shown previously (Chapter-I), poses dangerous consequences. It is worth mentioning here that the levels of metals recorded in sediments of Mahi estuary are many times higher than that reported for in the Antarctic ocean and Taiwan Erhjin Che coast.

The data shows alarmingly high levels of metal content in the soil along the channel. The background content of metals in the soil samples taken from, various parts of Baroda as well as 200m away from the channel on the left side, was 1.47 to 2.96 ppm for Cd, 1 to 11.4 ppm for Cu, 1.0 to 1.75 ppm for Ni, 1.0 to 1.4 ppm for Cr, 1 to 3.18 ppm for Pb and 159.9 to 321.5 ppm for Fe. Except for Fe, which is quite high, all other metals were more than 100 times less than that of Fe. The content of metals in the channel irrigated soil at five points down the channel range between 132 to 225 ppm for Cd, 105 to 256 ppm for Cu, 103 to 487 ppm for Ni, 110 to 470 ppm for Cr, 583 to 914 ppm for Pb, 702 to 900 ppm for Fe and 1068 to 2058 ppm for Zn. These values when compared with other heavily contaminated soil samples in India are much higher. For instance, compared to soil levels near thermal plants, the levels of Cu, Ni, Pb and Zn are 10 times, 10-18 times, 30 to 50 times, & 50 times higher respectively (*Patel & Panday,* 1988). Compared with the metal content from the soil around two Zinc smelters, the presently recorded levels were either same or 18 times more than the minimum levels for Zn, 20 times to 1000 times higher for Cd, 3-20 times more for Cu, 5-27 times more for Pb and 5-10 times high for Ni (Agrawal *et al.,*, 1988,; Totawat *et al.,* 1994).

It is clear from this, that continuous use of channel water for irrigation has built up very high levels of metal pollution in the soil along the channel. This is a bad prognosis as continuous use of the water even in future, keeping in mind the increasing pollution load of the channel effluent from year to year, is likely to increase to levels, which can find their way into the crop plants and vegetables grown by the village populace. This could have serious repercussions for vegetation in general and to human health in particular. It is ironical, that we are callously negligent of increasing metal pollution of the soil or, even of furture consequences to the ecosystem and to the populace of the area. It is indeed a matter of concern that though the metal contamination of soil along the channel is at an average 100 to 500 times more than the background level, we are callously ignorant and unconcerned, while an increase soil metal content in Sweden has already alerted the Swedish environmental protection agency and, are working on ways and means to safe gaurd the productivity of soil on long term basis (Timm, 1993). It is also reported that acidification of soil and water can make things worse, since it mobilizes the metals in the natural environment (Jannett *et al.*, 1980; Chan *et al.*, 1982). This is quite relevant in the present context, as there is a tendency for decreasing pH of the effluent discharge, which can lead to acidification of the soil along the channel.

The pollution of phreatic levels by seepage through soil and diffusion from polluted water bodies like rivers, lakes and ponds, is a definite phenomenon. This would ultimately be manifested by the appearance of pollutants in the well waters used for human consumption and irrigation. The present study on the water qualities of well water (situated at about 50-200 meters from the effluent channel on the left, whose water is used for irrigation in the land areas adjacent to the channel and about the same distance from the mini river on the right), has revealed alarmingly higher levels of TS, TDS, COD, chloride, sulphate, nitrate, and metals. Such changes in the chemical composition of the ground water caused by industrial pollution are also reported in other parts of the world. (Sobotivich *et al.*, 1992).

Higher content of chloride and sulphate in ground water, adjacent to a zinc smelter at Debari 14 km east of Udaipur, has been shown by Totawat *et al.*, (1994). The increase in the chloride and sulphate content in the ground water of the study area was in the range of 6-50 times as compared to the background levels estimated for water taken from other areas. Similarly the minimum to maximum range for TS, TDS, and COD are of the order of 5 to 12 times, 4 to 13 times, and 7 - 47 times respectively. Whereas there was no detectable BOD in well waters of nonpolluted areas, there was detectable range of BOD 3 - 29 mg/l in the well water of the study area.

Nitrates *per se* are not directly toxic to man but the problem arises from the fact that nitrates can get converted in our body into nitrates which can cause blood poisoning and also into cancer producing nitrosoamines. Considering this, and the average daily consumption by man from food as well as water, WHO has fixed the maximum concentration of nitrate permissible in drinking water as 50 mg/l. This standard has also been adopted by the EEC (Europeans Economic Commission) in its order number 18/778 15th July 1980. In France, the water works department and DDAS very closely monitor the nitrate levels in water supply particularly in problem areas to see that the nitrate level does not exceed above the standard levels. If the nitrate level exceeds above 500 mg/l, it is distributed only after a public warning has been issued. If the nitrat levels exceeds 100 mg, the water is declared unfit for drinking. It is clear that the wells in the study area have nitrate levels as high as 700 mg/1 which is 200 times greater than the background levels in the control wells and 14 times greater than the prescribed standard safe level recommended by WHO and EEC.

Like the undesirable changes in the above physico-chemical parameters, another aspect of concern is the increasing content of metals. Though the metal content of water adjacent to effluent channel is lower than the WHO standard values (Table 5); except for Cd and Pb, they are many times greater than the background levels in unpolluted areas. The increase is in the range of 2-9 times for copper, 2-10 times for chromium, 3-17 times for nickel, 5-9 times for Zinc, 5 times for lead, 4-12 times for iron and 14-30 times for cadmium. This suggests a gradual increase over the years and, this continued trend can lead to metal levels in exceess of the prescribed standard values. In case the of Cd, the minimum level obtained is 3 times the WHO range and the highest level obtained is 14 times more than the WHO range. Similarly, the higher level of Pb in some of the wells is already in the WHO range.

Rao and Rao 1992, have reviewed the metal content of polluted and unpolluted waters, in different parts of the country and also the background levels in some of the wells in different cities. Though in general, the contents of various metals seem to be transiently below the reported levels in the waters of polluted areas of other parts of the country, the relatively higher levels in the underground water of effluent channel area as compared to the background

TABLE 5 : WATER QUALITY GUIDELINES FOR VARIOUS USES *

WATER QUALITY VARIABLE	DRINKING WATER	IRRIGATION WATER	
		NO USE RESTRICTION	SEVERE RESTRICTION
MICROBILOGICAL CRITERIA			
- TOTAL COLIFORMS	-10		
(PER 100 ml)	0		<1000
- FECAL COLIFORMS			
(PER 1 ml)			
ORGANIC POLLUTION			
- DISS. OXYGEN (mg/l)			
- BOD,COD,TOC			
NITROGENOUS COMPOUNDS			
- NITRATE-N (mg/l)	10	<5	>30
- AMMONIA-N (mg/l)			
- KJELDAHL-N (mg/l)			
SALINITY & SPECIFIC IONS			
- pH	(6.5-8.5)	6.5-8.4	6.5-8.4
- TOTAL DISSOLVED SOLIDS		450	>2000
TDS (mg/l)	1000		
- FLUORIDE (mg/l)	1.5	1	15
- CHLORIDE (mg/l)	250	<3	>10
- SULFATE (mg/l)	400		
- BIOCARBONATE (mg/l)		<1.5	>8.5
- HARDNESS (mg CaCO3/l)		500	
INORGANIC MICROPOLLUTANTS	(mg/l)		
- CADMIUM	0.005	0.01	0.05
- CHROMIUM	0.05	0.1	1
- COPPER	1	0.2	5
- CYANIDE	0.1		
- IRON	0.3	5	20
- LEAD	0.05	5	10
- NICKEL		0.2	2
- ZINC	5	2	10

* Assessment of fresh water quality, 1988
United Nations Environment Programme (UNEP),
World Health Organisation (WHO).

levels in other areas, and even the exceedingly high levels of Cd and Pb above the prescribed levels, are unequivocal testimony to the increasing threat of potential contamination of acquifers in the study area. In the wake of increasing load of pollutants in the effluent channel and, uncontrolled pilferage of channel water for irrigation, coupled with the steady disposal of untreated effluent into the Mini river, it is predictable that underground acquifers in the area would get so contaminated as to make it undesirable for human consumption or usage.