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Influence of treated paper board mill effluent on soil and ground water quality parameters

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Abstract : Field survey was carried out to collect soil and water samples of thirty-five numbers representing in and around the factory area covering Mandaraikadu, Devanapuram, P. Thekkampatti, C. Thekkampatti, C. Kandiyur and R. Rajapuram villages. Five hundred grams of soil samples were collected once in three months from September 2000 to September 2001 to assess the changes in soil quality parameters if any due to effluent contamination. One litre volume of water sample was collected at monthly intervals from October 2000 to September 2001 to monitor the changes in the ground water quality due to effluent discharge for crop production. The qualities of groundwater samples from different locations were compared with samples collected near intake river water (control) where the possibility of ground water pollution due to paper mill effluent was remote. The soil was analyzed for its chemical properties viz., pH, EC, OC, Available NPK, Exchangeable Na and SAR. The pH, EC, OC, available nutrients (NPK), exchangeable Na and SAR were high in effluent irrigated soils in and around the factory regions compared to the Bhavani river water irrigated soils. The above soil properties increased due to continuous effluent irrigation at periodical intervals of analysis. Observation wells in and around the factory region had high pH than that of Bhavani river water. The EC, chloride, sulphate and sodium were high in the effluent irrigated area. The BOD in the well water samples varied from 7.7 to 8.9 mg L^{-1} whereas river water recorded the BOD ranged from 6.2 to 7.2 mg L^{-1}. The COD of the well water samples were also high in effluent irrigated area (67 to lll mg L^{-1}). The potential salinity was lesser than 6 c mol L^{-1} and the SAR was below 2.

Key words : pH, EC, treated paper mill effluent, potential salinity, sodium absorption ratio (SAR)

Introduction

The sustainability of environmental quality is an accepted national goal. Agriculture is also faced with a number of constraints. Land application of industrial effluent and sludge for the crop production is an effective method of waste disposal wherein the valuable nutrients are recycled back into the ecosystem. Such water reuse accomplishes several purposes such as minimizing the cost of waste water treatment and disposal, providing much needed nutrients and fertilizers to the soil when used for agriculture and particularly alleviating the shortfall of water supply with a dependable continuous supply of waste water. Among the major industries in India, pulp and paper industry being highly water intensive regarded as a major pollutant of soil and water resources. They rank third in terms of fresh water withdrawal after primary metal and chemical industries in the world (Kallas and Munter, 1994). The production capacity of the BIPCO factory is around 300 tonnes of duplex board per day and it consumes around 2500-3000 m^3 of water and discharges around 2100 - 2600 m^3 of waste water per day. The waste water is properly treated in modernized effluent treatment plant and is being completely utilized for irrigation, in about 80 ha of virgin land owned by the factory.

Materials and Methods

The BIPCO is situated in Thekkampatti village, Mettupalayam, Coimbatore District. Coimbatore lies in 11.02° North latitude and in

Table 1. pH of soil samples in and around the Factory Area

Location	Sep-00	Dec-00	Mar-01	Jun-01	Sep-01	Mean
Mandarikadu	6.52	6.55	6.70	6.66	6.61	6.61
Devanapuram	6.51	6.54	6.67	6.64	6.61	6.59
P. Thekkampatti	6.63	6.66	6.82	6.76	6.67	6.71
C. Thekkampatti	6.92	6.93	7.06	7.01	6.95	6.97
Chinna kandiyur	6.78	6.81	6.95	6.90	6.83	6.85
Rangarajapuram	6.95	6.99	7.16	7.08	6.95	7.03
Mean	6.69	6.71	6.86	6.81	6.74	6.76
Control (river water)	7.02	7.15	7.10	7.05	7.10	7.08

Table 2. EC (dSm^{-1}) of soil samples in and around the Factory Area

Location	Sep-00	Dec-00	Mar-01	Jun-01	Sep-01	Mean
Mandarikadu	0.05	0.06	0.10	0.08	0.06	0.07
Devanapuram	0.04	0.05	0.09	0.08	0.06	0.06
P. Thekkampatti	0.05	0.06	0.11	0.09	0.06	0.07
C. Thekkampatti	0.04	0.05	0.10	0.08	0.06	0.07
Chinna kandiyur	0.04	0.05	0.09	0.08	0.06	0.06
Rangarajapuram	0.06	0.07	0.11	0.09	0.07	0.08
Mean	0.05	0.06	0.10	0.08	0.06	0.07
Control (river water)	0.04	0.05	0.07	0.06	0.04	0.05

Table 3. Organic Carbon per cent of soil samples in and around the Factory Area

Location	Sep-00	Dec-00	Mar-01	Jun-01	Sep-01	Mean
Mandarikadu	0.49	0.50	0.58	0.55	0.53	0.53
Devanapuram	0.45	0.47	0.54	0.49	0.47	0.48
P. Thekkampatti	0.44	0.46	0.52	0.49	0.46	0.47
C. Thekkampatti	0.48	0.49	0.54	0.52	0.50	0.51
Chinna kandiyur	0.44	0.45	0.51	0.49	0.46	0.47
Rangarajapuram	0.44	0.46	0.48	0.46	0.47	0.46
Mean	0.46	0.47	0.53	0.50	0.48	0.49
Control (river water)	0.36	0.37	0.45	0.43	0.43	0.41

Table 4. Exch. Na (cmol (+) kg^{-1}) of soil samples in and around the Factory Area

Location	Sep-00	Dec-00	Mar-01	Jun-01	Sep-01	Mean
Mandarikadu	5.94	6.52	7.07	6.77	6.55	6.57
Devanapuram	5.97	6.62	7.10	6.79	6.40	6.58
P. Thekkampatti	5.92	6.35	7.20	6.76	6.37	6.52
C. Thekkampatti	5.96	6.46	7.11	6.60	6.47	6.52
Chinna kandiyur	6.06	6.55	7.01	6.40	6.19	6.44
Rangarajapuram	6.10	6.49	7.21	6.70	6.52	6.60
Mean	5.98	6.50	7.11	6.68	6.41	6.54
Control river water	5.75	6.98	6.82	6.52	6.31	6.42

Table 5. The SAR of soil samples in and around the Factory Area

Location	Sep-00	Dec-00	Mar-01	Jun-01	Sep-01	Mean
Mandarikadu	3.14	3.50	3.83	3.65	3.50	3.53
Devanapuram	3.16	3.57	3.85	3.66	3.42	3.53
P. Thekkampatti	3.17	3.39	3.90	3.64	3.47	3.51
C. Thekkampatti	3.29	3.60	3.98	3.67	3.61	3.63
Chinna kandiyur	3.25	3.50	3.77	3.39	3.28	3.44
Rangarajapuram	3.36	3.53	3.93	3.61	3.54	3.59
Mean	3.21	3.51	3.87	3.61	3.47	3.54
Control (river water)	2.95	3.67	3.65	3.46	3.28	3.39

Table 6. Available N (kg ha^{-1}) of soil samples in and around the Factory Area

Location	Sep-00	Dec-00	Mar-01	Jun-01	Sep-01	Mean
Mandarikadu	135	135	138	136	136	136
Devanapuram	142	140	146	142	143	142
P.Thekkampatti	145	144	148	144	146	145
C.Thekkampatti	144	142	144	145	144	144
Chinna kandiyur	153	151	151	149	143	149
Rangarajapuram	147	145	145	143	139	144
Mean	144	142	145	143	142	143
Control (river water)	141	142	141	139	135	140

Table 7. Available P(kg ha^{-1}) of soil samples in and around the Factory Area

Location	Sep-00	Dec-00	Mar-01	Jun-01	Sep-01	Mean
Mandarikadu	28.75	27.96	28.61	28.69	27.08	28.22
Devanapuram	28.53	27.94	28.22	28.09	27.38	28.03
P.Thekkampatti	29.75	28.47	29.51	29.50	28.11	29.07
C.Thekkampatti	30.48	28.97	30.30	30.29	28.45	29.70
Chinna kandiyur	31.66	30.08	31.40	30.98	29.57	30.74
Rangarajapuram	31.46	29.12	31.30	28.41	26.84	29.43
Mean	29.88	28.65	29.66	29.33	27.94	29.09
Control (river water)	28	28	29	29	26	28

77.03° East longitude. The mean annual rainfall is 700 mm. Soil is of red loamy type and classified as Typic Ustalf. River, Canals and wells are the main sources of irrigation in this region. Field survey involved collection and analysis of thirty-five numbers of ground water samples representing in and around the factory areas covering Mandaraikadu, Devanapuram, P. Thekkampatti, C. Thekkampatti, C. Kandiyur and R. Rajapuram villages. Five hundred grams of soil samples in 0 - 30 cm depth were collected once in three months to assess the changes in soil quality parameters if any due to effluent contamination. The collected soil samples were dried in shade for two days, powdered gently with a wooden mallet and sieved through a 0.2 to 2 mm sieve. The material which passed through the sieve was taken for further analysis. The pH, EC, OC, available nutrients (NPK), exchangeable Na and SAR were analysed as per the standard procedure. The water samples were

collected from Open / Bore wells to monitor the changes in the ground water quality due to effluent discharge for crop production in 35 locations of in and around of the factory area. One litre volume of water was collected in polyethylene container at monthly intervals from October 2000 to September 2001. The quality of groundwater samples from different locations were compared with samples collected near intake river water (control) where the possibility of ground water pollution due to BIPCO effluent was remote. Water samples collected from the wells were kept in freezer at 4°C to avoid microbial activity. Observation wells in and around the factory region and the river water were analyzed for the pH, EC, chloride, sulphate and sodium as per the standard procedure (Anonymous, 1989). The Potential salinity and SAR were assessed.

Results and Discussion

The pH of the soil increased progressively in all the villages, which was acidic to neutral in nature.

Fig. 1. Na of water samples in and around the factory area

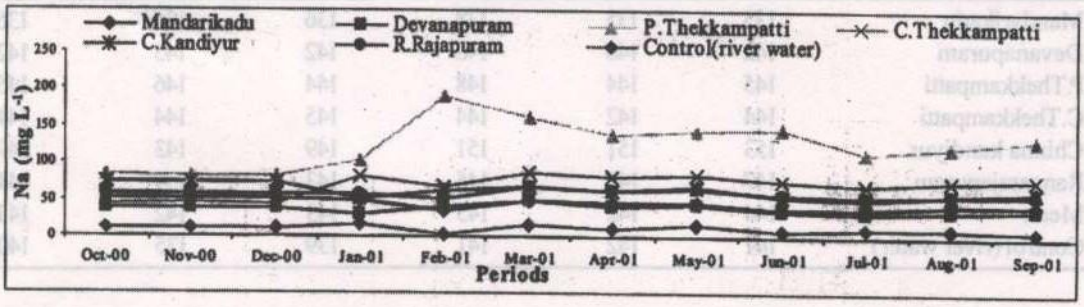

Fig. 2. Cl^- of water samples in and around the factory area

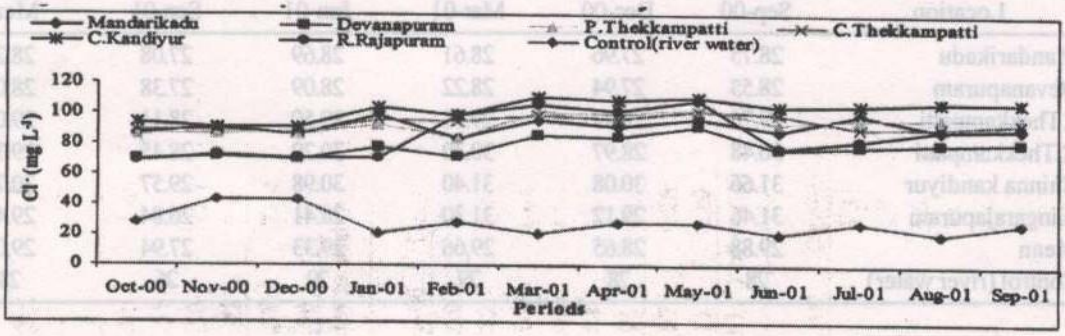

Fig. 3. SO_4^- of water samples in and around the factory area

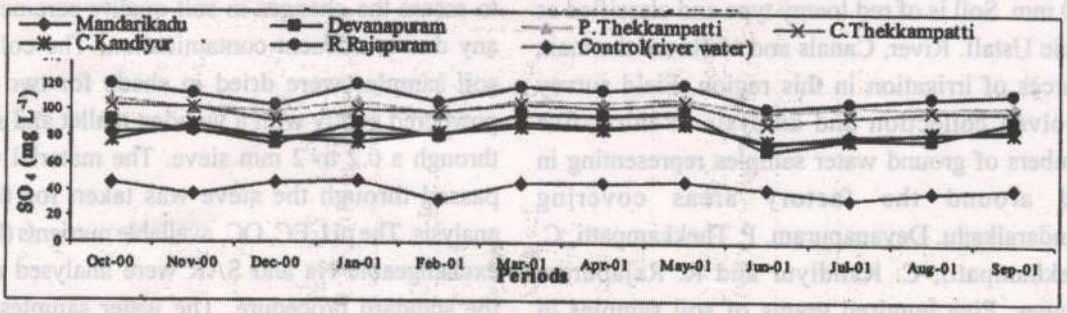

Table 8. pH of water samples in and around the factory area

Location	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Au -01	Sep -01	Mean
Mandarikadu	7.48	7.53	7.53	8.30	8.25	8.38	8.37	8.41	8.26	8.32	8.33	8.35	8.12
Devanapuram	7.43	7.45	7.46	8.35	8.30	8.44	8.42	8.47	8.43	8.36	8.38	8.41	8.16
P. Thekkampatti	7.63	7.66	7.68	8.74	8.71	8.78	8.76	8.81	8.77	8.73	8.74	8.74	8.48
C. Thekkampatti	7.51	7.55	7.55	8.43	8.41	8.53	8.52	8.55	8.46	8.48	8.52	8.50	8.25
C. Kandiyur	7.50	7.50	7.51	8.65	8.62	8.66	8.64	8.67	8.65	8.61	8.62	8.64	8.36
R. Rajapuram	7.41	7.42	7.44	8.35	8.32	8.47	8.46	8.49	8.53	8.36	8.39	8.43	8.17
Mean	7.50	7.53	7.54	8.48	8.44	8.55	8.54	8.58	8.51	8.49	8.51	8.52	8.26
Control (river water)	7.27	7.30	7.35	7.54	7.52	7.65	7.63	7.66	7.47	7.56	7.59	7.62	7.51

Table 9. EC (dSm^{-1}) of water samples in and around the factory area

Location	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Au -01	Sep -01	Mean
Mandarikadu	0.66	0.68	0.70	1.87	0.99	1.07	1.03	1.09	1.01	0.92	0.95	0.98	1.00
Devanapuram	0.71	0.72	0.74	0.81	1.04	1.00	0.98	1.03	0.98	0.87	0.93	0.97	0.90
P. Thekkampatti	0.90	1.07	1.06	0.88	0.92	0.98	0.96	1.01	0.95	0.91	0.92	0.94	0.96
C. Thekkampatti	1.00	1.02.	1.04	0.94	1.13	1.05	1.02	1.07	1.00	0.97	0.99	1.00	1.02
C. Kandiyur	0.83	0.84	0.85	0.66	0.79	0.82	0.80	0.85	0.74	0.68	0.77	0.79	0.79
R. Rajapuram	0.88	0.91	0.91	0.85	1.08	1.08	1.06	1.10	1.00	0.91	0.94	1.03	0.98
Mean	0.82	0.87	0.88	1.02	0.99	1.00	0.97	1.02	0.95	0.88	0.92	0.95	0.94
Control river water	0.09	0.11	0.10	0.15	0.07	0.15	0.12	0.16	0.15	0.18	0.15	0.09	0.13

Table 10. Potential Salinity (c mol L^{-1}) of water samples in and around the factory area

Location	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Au -01	Sep -01	Mean
Mandarikadu	3.3	3.4	3.3	3.7	3.2	3.5	3.6	3.7	3.3	3.7	3.4	3.5	3.5
Devanapuram	2.9	2.9	2.7	3.1	2.9	3.4	3.4	3.6	2.9	3.0	3.1	3.3	3.1
P. Thekkampatti	3.6	3.5	3.5	3.7	3.4	3.9	4.0	4.1	3.7	3.8	3.8	3.9	3.7
C. Thekkampatti	3.6	3.6	3.4	3.7	3.7	3.8	3.9	4.0	3.8	3.6	3.6	3.7	3.7
C. Kandiyur	3.4	3.5	3.4	3.7	3.7	4.0	4.0	4.1	3.8	3.8	3.9	3.9	3.8
R. Rajapuram	3.2	3.2	3.1	3.2	3.9	4.1	4.2	4.3	3.3	3.4	3.7	3.8	3.6
Mean	3.3	3.4	3.2	3.6	3.4	3.7	3.8	3.9	3.4	3.6	3.6	3.7	3.5
Control (river water)	1.3	1.6	1.7	1.1	1.1	1.3	1.1	1.3	1.0	1.2	1.0	1.2	1.2

Table 11. SAR of water samples in and around the factory area

Location	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Au -01	Sep -01	Mean
Mandarikadu	1.326	1.320	1.300	1.045	0.775	0.785	1.011	0.952	1.002	0.824	0.912	0.913	1.014
Devanapuram	0.986	0.973	0.974	0.730	0.768	0.896	1.031	0.920	0.948	0.749	0.810	0.835	0.885
P. Thekkampatti	2.304	2.155	2.135	2.753	3.719	4.661	3.775	3.550	3.445	3.026	3.000	3.183	3.142
C. Thekkampatti	1.102	1.096	1.084	2.097	1.732	1.597	1.853	2.089	1.899	1.808	1.814	1.757	1.661
C. Kandiyur	2.111	2.106	2.089	1.221	1.307	1.442	1.567	1.455	1.465	1.211	1.255	1.455	1.557
R. Rajapuram	1.402	1.402	1.378	1.377	1.350	1.182	1.563	1.484	1.529	1.256	1.314	1.361	1.383
Mean	1.54	1.50	1.49	1.57	1.68	1.88	1.86	1.80	1.77	1.53	1.57	1.63	1.65
Control (river water)	0.564	0.602	0.553	0.764	0.245	0.152	0.631	0.533	0.722	0.448	0.430	0.317	0.497

Table 12. BOD (mg L^{-1}) of water samples in and around the factory area

Location	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Au -01	Sep -01	Mean
Mandarikadu	7.8	8.0	7.9	7.4	7.9	8.7	8.6	9.0	8.3	7.9	8.1	8.5	8.2
Devanapuram	7.7	8.3	8.4	7.8	8.4	9.1	9.0	9.2	8.5	8.4	8.8	8.8	8.5
P. Thekkampatti	7.8	8.0	8.1	8.0	7.5	8.8	8.8	9.0	8.2	8.3	8.3	8.6	8.3
C. Thekkampatti	7.7	8.0	8.2	7.7	7.9	8.7	8.5	8.8	8.2	8.1	8.3	8.3	8.2
C. Kandiyur	7.6	7.9	8.1	7.2	8.0	8.3	8.1	8.4	8.3	7.8	8.3	7.9	8.0
R. Rajapuram	7.8	8.1	8.3	7.9	7.9	8.7	8.6	8.8	8.4	8.2	8.3	8.4	8.3
Mean	7.7	8.0	8.1	7.7	7.9	8.7	8.6	8.9	8.3	8.1	8.3	8.4	8.2
Control (river water)	6.2	6.6	6.5	6.2	6.8	6.9	7.2	7.05	6.8	7.05	7.15	7.2	6.80

Table 13. COD (mg L^{-1}) of water samples in and around the factory area

Location	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Au -01	Sep -01	Mean
Mandarikadu	67	69	64	117	77	112	107	120	96	98	102	108	95
Devanapuram	61	64	59	112	98	111	107	113	80	82	92	103	90
P. Thekkampatti	71	80	75	162	91	114	107	123	82	84	98	103	99
C. Thekkampatti	67	72	77	99	67	101	97	104	80	85	89	95	86
C. Kandiyur	67	70	67	131	45	96	92	100	64	66	79	83	80
R. Rajapuram	69	69	59	128	43	90	87	96	69	88	83	85	81
Mean	67	71	68	125	75	106	101	111	80	84	92	98	90
Control (river water)	48	64	64	16	48	70	71	73	64	62	65	68	59

The mean pH of the soil samples collected at periodical intervals increased from 6.69 to 6.86 due to continuous BIPCO effluent irrigation, whereas the values in river water irrigated soils ranged from 7.02 to 7.15. The highest pH was observed in March 2001, which might be due to retention of more ions in the soil due to evaporation loss. Among the villages, R. Rajapuram recorded the highest pH value, which is located near the treated effluent irrigated area (Table 1). The seepage of water from Mandaraikadu where the effluent is being applied directly to sugarcane crop might have increased the soil pH at R. Rajapuram. Ground water investigations were carried out by collecting water samples from observation wells at monthly intervals revealed that the pH was more when compared to river water and saline in nature, which might be due to the application of inorganic fertilizers in and around the factory area. The mean pH of the well water increased from 7.50 to 8.58 in continuous effluent irrigation (Table 8). The pH of the water samples was high during the summer (March-May) and low during monsoon season (October-December). Among the villages, P. Thekkampatti recorded high pH followed by C. Kandiyur.

The EC of the soils in around the factory area was high (0.05-0.10 dSm^{-1}) compared to river water irrigated soil. The highest EC was recorded in the month of March 2001 (summer). The soluble salt concentration decreased during the monsoon seasons (December 2000). Mandaraikadu (factory site) recorded the highest EC values because of the continuous effluent irrigation. R. Rajapuram was also recorded the highest EC values because of the fact that it is located very close to factory site. Due to high evaporation loss in summer (March 2001), the soil EC increased invariably in all the villages. During monsoon season, the soil EC decreased due to leaching of soluble salts (Table 9). The increase in soluble salt content in the soil could be ascribed to the salt content of effluent. Reddy *et al.* (1981) have also reported that continuous irrigation with pulp and paper mill resulted in increased soluble salts in soil. Similar observations were reported by Udayasoorian *et al.* (1999a) in TEWLIS area near Karur where the treated paper mill effluent was continuously used for irrigation over eight years. The EC of the well water ranged from 0.82 to 1.02 dSm^{-1} (Table 12) and for river water from 0.09 to 0.18 dSm^{-1} at different intervals. C. Thekkampatti recorded higher EC whereas C. Kandiyur showed comparatively lower EC value. The increasing trend of EC was observed in all the villages due to continuous effluent irrigation inside the factory area for sugarcane. The highest EC of 1.00, 0.97, 1.02 dSm^{-1} was observed in March, April and May 2001 respectively, whereas October, 2000 recorded lower EC value of 0.82 dSm^{-1}. This confirms the movement of salt through seepage water from effluent irrigated area (Mandaraikadu) to the adjacent villages over the past several years. (Udayasoorian *et al.*, 1999b).

The collected soil samples also recorded more organic carbon (0.46-0.53 per cent) compared to river water irrigated soil. Among the villages, Mandaraikadu (factory site) recorded higher organic carbon content than other villages (Table 3). The organic carbon content was increased during the month of March 2001. A gradual increase in soil organic carbon content in these villages might be due to accumulation of suspended and dissolved organics present in the effluent which inturn contribute to the built up of organic matter. Similar observations were made by Udayasoorian *et al.* (1999b) in TEWLIS area where the treated paper mill effluent was used for irrigation.

Exchangeable sodium content was low in the river water irrigated soils compared to effluent irrigation. The mean exchangeable sodium was found to be in the range of 5.98 to 7.11 cmol (+)

kg $^{-1}$. The sodium content was very high in Rangarajapuram during the period of March 2001 (Table 4). The fast movement of soluble ions present in effluent through seepage water to other nearby villages might have been the reason for increased exchangeable cations. Higher concentration of exchangeable cations under effluent irrigation was reported by a number of workers (Reddy *et al.*, 1981; Gomathi and Oblisami, 1992). Effluent irrigation for over three years increased exchangeable cations in soil (Palaniswami and Sree Ramulu 1994). The sodium content was more in the well water than that of river water and it increased from 57.3 to 83.1 mg L^{-1} in the well water during different period of analysis. Two fold increases in the sodium content was observed in the P. Thekkampatti village. Devanapuram and Mandaraidadu (factory site) recorded very low sodium in the water samples. Among the seasons, summer months recorded higher sodium than the monsoon seasons. High Na (Fig. 1) in the effluent through leaching and infiltration might have settled in the wells of nearby villages. The sodium content was very high in P. Thekkampatti, - which may be due to its location in down slope leading to the accumulation of sodium in ground water. The sodium content has increased invariably in all the villages during March - May 2001 (summer) may be due to seasonal effect.

The chloride and sulphates concentrations were higher in the factory regions of BIPCO effluent irrigated area, whereas river water recorded very low concentration of chloride and sulphates. Chloride increased from 82.4 to 101.1 mg L^{-1} in the well water whereas river water ranged from 21.3 to 42.5 mg L^{-1}. The sulphate content ranged from 84.5 to 101.4 mg L^{-1} in the well water and 31.6 to 45.8 mg L^{-1} in the river water. Trade effluent discharged on land for irrigation should have chloride and sulphate of less than 600 and 1000 mg L^{-1} as prescribed by TNSPCB (ISI, 1977). The chloride content recorded in the observation wells in and around the factory site was below the permissible limit only. However, the chloride and sulphate contents have increased in and around the factory area, when compared to river water irrigated area (Fig.2 and Fig.3). This might be due to the movement of chloride and sulphate through seepage water. During the study period, the summer months (March -May 2001) showed an increasing trend of chloride and sulphate due to the influence of high temperature. The per cent sodium in the well water samples varied from 25.16 to 29.21 while river water recorded 7.23 to 30.34 per cent. The highest per cent sodium was recorded in P. Thekkampatti and the lowest value was observed in Devanapuram (Fig.5).

The potential salinity of the well water was very high and ranged from 3.2 to 3.9 cmol L^{-1}. The highest potential salinity was recorded in C. Kandiyur followed by P. Thekkampatti and C. Thekkampatti (Table 10). The later two were more or less same. Among the seasons, summer months recorded higher salinity than the monsoon season of September-November 2001. The potential salinity (PS) of well water was analyzed 'medium' at periodical intervals, which indicated that the chlorides and sulphates gradually increased in ground water in and around the factory area. Devanapuram showed less potential salinity when compared to other villages, which might be due to its location at the middle of the steep slope and the chances of accumulation of chloride and sulphates are remote. The well water did not cross the critical limit of 20 c mol L^{-1} reported by Doneen (1965), whereas river water had 'low' (1.0 to 1.7 c mol L^{-1}) potential salinity.

The mean SAR of the soil samples collected in the effluent irrigated soil ranged from 3.3 to 3.9. It was high when compared to river water irrigated

soils. The SAR of the soil was less than 4 c mol L^{-1} and falls the category of 'low' under continuous effluent irrigation over a period of several years (Table 5). Similar findings have been reported by Pushpavalli (1990), which might be due to the built up of exchangeable calcium and magnesium in effluent irrigated soils. The SAR of the well water sample was high in effluent irrigated soil (1.49 to 1.88) while that of river water recorded very less SAR (0.152 to 0.764) (Table 11). The SAR of the ground water in and around the factory area and river water falls under 'low' category according to USDA system of classification (1954). The SAR was below 2 in both ground and river water samples. In few places the SAR goes up to 19. It reveals the accumulation of salt concentration.

Available nutrient status (except available K) of the soil in and around the factory area was higher when compared to river water irrigated soil (Table 6 & 7). An increasing trend on available nutrient status was observed invariably at all the villages due to the impact of continuous effluent irrigation at Mandaraikadu from where the seepage water containing more of N and P pollutes the other villages also. The BOD in the well water samples varied from 7.7 to 8.9 mg L^{-1} whereas river water recorded the BOD ranged from 6.2 to 7.2 mg L^{-1} (Table 12). The BOD of the water samples increased during the summer season (March-May 2001) and again decreased drastically in the monsoon season. Among the villages Devanapuram recorded the highest BOD and the lowest BOD was observed in monsoon (October, 2000). The similar trend was observed in COD except the highest COD was recorded in the P. Thekkampatti village (99 mg L^{-1}). The COD of the well water samples were high in effluent irrigated area (67 to 111 mg L^{-1}) whereas in river water recorded very less COD in the range of 16 to 73 mg L^{-1} (Table 13).

Finally the results revealed that the pH, EC, OC, available nutrients (NPK), exchangeable Na and SAR were high in effluent irrigated soils in and around the factory regions when compared to Bhavani river water irrigated soils. The above soil properties increased due to continuous effluent irrigation at periodical intervals of analysis. Observation wells in and around the factory region irrigated by paper board mill effluent had high pH than that of Bhavani river water. The EC, chloride, sulphates and sodium were high in the effluent irrigated area. The potential salinity was lesser than 6 c mol L^{-1}. The SAR was below 2. The over all rating of most of the ground water tested in and around the factory area fall under C_1S_1, category as per the USDA classification of 1954 and it is suggested that the ground water could be used for agricultural purposes.

References

Anonymous. (1989). **Standard methods for the examination of water and waste water**. Amer. Pub. Health Assoc. and Amer. Water Works Assoc. and Amer. Water Pollution Cont. Federation, Broadway, New York, p.1193.

Doneen, L.D. (1965). Water quality for Agricultural Use. Department of Irrigation, University of California, Davis, p.48.

Gomathi, V. and G. Oblisami. (1992). Effect of pulp and paper mill effluent on germination of tree crops. **Indian J. Environ. Hlth., 34**: 326-328.

ISI (Indian Standard Institute). (1977). Indian Standard: Tolerance limits for industrial effluents for discharge on land for irrigation. **I.S.**, : 3307.

Kallas, J. and R. Munter. (1994). Post-treatment of pulp and paper industry waste waters using oxidation and adsorption processes. **Wat. Sci. Technol., 29**: 259-272.

Palaniswami, C. and U.S. Sree Ramulu. (1994). Effects of continuous irrigation with paper factory effluent on soil properties. J. Indian Soc. Soil Sci., 42: 139-140.

Pushpavalli, R. (1990). Studies on the characterization of pulp and paper mill effluent and it's effect on soil profile characteristics and on germination, yield and juice quality of sugarcane (Var. CO 63004 and COC 671) M.Sc. (Ag.) Thesis, Tamil Nadu Agrl. Univ., Coimbatore.

Reddy, M.R., S. Jivendran and S.C. Jain. (1981). Paper mills effluent for sugarcane irrigation. **IAWPC Technol. Annu.**, 8:129-146.

Udayasoorian, C., P. Dhevagi and P.P. Ramaswami. (1999a). Case study on the utilization of paper and pulp mill effluent irrigation for field crops. **In** : Proceedings of the workshop on Bioremediation of polluted habitats, Tamil Nadu Agricultural University, Coimbatore, Mar. 22-23, pp: 71-72.

Udayasoorian, C., K. Mini and P.P. Ramaswami. (1999b). Bagasse pith compost - An effective ameliorant in paper mill polluted soil environments. **In** : Proceedings of the workshop on Bioremediation of polluted habitats, Tamil Nadu Agricultural University, Coimbatore, Mar. 22-23.

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