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Groundwater Quality in Paper Mill Effluent Irrigated Area with Special Reference to Organochlorine Residues and Heavy Metals

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The utilization of wastewater for irrigation has increasingly gained importance in various countries of the arid and semi-arid regions, as water is becoming a scarce commodity. Due to the strict enforcement of effluent discharge, industries are opting for reuse of effluent for irrigation. Though the concept seems to be promising the real success can be attributed only if there is no toxic accumulation in the long run. The sustenance of the ground water quality in the effluent irrigated area has been a cause for concern. (Farid et al. 1993; Gallegos et al. 1999). The enhanced transport of pesticides to groundwater and accumulation of heavy metals in effluent irrigated land has also been reported (Graber et al. 1995). The environmental contamination by organochlorine pesticide residues is of great concern due to their toxicity and persistent nature. It is therefore indispensable to investigate whether inadmissible level of pesticide residues and heavy metal concentration are present in the groundwater of effluent irrigated area. If so, better management practices can be undertaken for the long-term sustainability of the effluent irrigation schemes. The present study has therefore been undertaken to assess the current status of water quality, pesticide residue levels and heavy metal concentrations in the groundwater system of effluent irrigated area of Pallipalayam, Tamil Nadu, India.

MATERIALS AND METHODS

The study area is located between 11° 18' 00" - 11° 23' 00"N and 77° 44' 00" - 77° 50' 00"E on the banks of river Cauvery at Pallipalayam in Namakkal district Tamil Nadu, India (Fig.1). The effluent irrigation program was introduced in 1980. The unique feature of this scheme is that it brought about fusion of the triangular interest viz. paper mill, sugar mill and farmers of the adjoining area. The pulp and paper unit having shifted its raw material choice from forest based hard wood to bagasse, had set up its own sugar mill - adjoining the paper unit. The sugar mill would supply bagasse to the pulp unit after extraction and the paper mill in turn encourages the farmers under its effluent irrigation scheme to grow sugarcane in 75% of the crop area thereby ensuring that its sugar unit gets adequate cane supply. Thanks to this effluent irrigation program adjoining barren land has been converted into irrigated area. Based on the acceptability of effluent irrigation program by the farming community, at present there are four lift irrigation schemes in operation and these schemes are introduced at different

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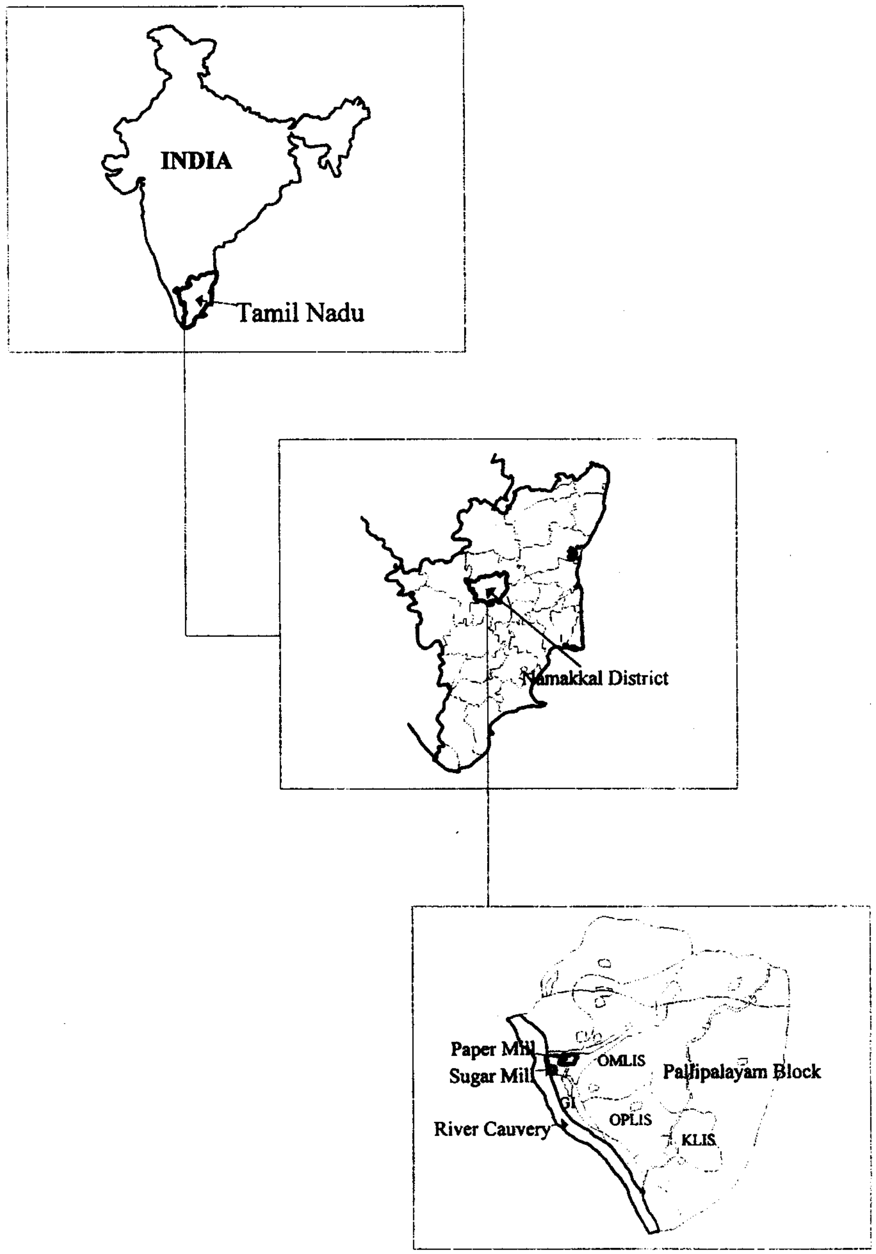

Figure 1. Location map of the study area

period of time viz. Odapalli Papanpalayam Lift Irrigation Scheme (OPLIS) in 1983, Odapalli Mukuparai Lift Irrigation Scheme (OMLIS) in 1986, Kattur Lift Irrigation Scheme (KLIS) in 1989 and Gravity irrigation (GI) which is more than 30 years old.

In order to assess the impact of effluent irrigation on the groundwater quality, water samples were collected from three bore wells from each irrigation scheme. The water quality parameters viz. pH, electrical conductivity, total ammonia nitrogen (TAN), nitrite nitrogen, nitrate, phosphate, total phosphorous and chemical oxygen demand (COD) were assessed using the standard procedure (APHA, 1995). For the analysis of heavy metals, water samples collected were preserved in acidic medium (pH <2) by adding 0.5 M HNO_3 as preservative and stored in the laboratory at 4° C in a refrigerator and analyzed using atomic absorption spectrophotometer (APHA 1995).

Water samples for the pesticide analysis were collected from the identified bore wells in a glass container and preserved in refrigerator until analyzed. Extraction of water samples for organochlorines was carried out following the standard method (APHA 1995). In this method, one litre unfiltered water sample was transferred to a 2 litre separatory funnel. Sample container was rinsed with dichloromethane and hexane (15:85 v/v) and washings were also transferred to the funnel. Water sample was then extracted twice with dichloromethane and hexane (15:85 v/v). After clear separation of the aqueous and hexane layers, the aqueous layer was discarded and combined hexane layers were reduced in volume by K.D. evaporator. A clean up was performed by Florisil (Aldrich 675°C activated, 60/100 mesh PR grade) column chromatograph. The glass column used was 6' in length and had an inner diameter of 1/4" packed with 1.5 % OV-17 + 1.95% OV-210 on 80/100 mesh chromosorb WHP. The analysis was recorded by the ORACLE-2 Software program. Pure and dry nitrogen was used as a carrier gas. The flow rate of N_2 gas was maintained at 60 ml/min. The injector, oven and detector temperature were maintained at 200, 220 and 275°C, respectively. All chemicals used were HPLC grade. Pesticide standards were procured from E. Merck (Dr. Ehrenstorfer, Germany). The detection limits of the organochlorine pesticides are given in Table 1.

RESULTS AND DISCUSSION

The results of the analysis of groundwater samples collected from the effluent irrigated areas with respect to different period of irrigation are presented in Table 2. The pH was found to be alkaline, ranging from 7.59-7.82. The electrical conductivity in 30 years effluent irrigated area was 1.87 dS/m whereas in 12 years irrigated area it was 1.38 dS/m indicating the slight increase in electrical conductivity with period of irrigation. The total ammonical nitrogen and nitrite concentrations ranges from 0.240 to 0.289 mg/l and 0.018 to 0.022 mg/l respectively showing that these parameters have no significant relation with respect to period of irrigation. It could be observed that the period of effluent irrigation increases the concentrations of nitrate in the ground water samples. The

Table 1. Detection limit of organochlorine pesticide residues

Organochlorines	Detection Limit (ng/l)
HCH (α,β,γ)	3-10
Heptachlor	3
Aldrin	4
Dieldrin	2
Endrin	6
Endosulphan (α,β, sulphate)	4-66
DDT (DDD, DDE)	20-25

nitrate concentration was 40, 20, 18 and 9 mg/l in the groundwater samples collected from more than 30 years, 18 years, 15 years and 12 years effluent irrigated area respectively. This is well within the permissible level of 45 mg/l. High levels of nitrate in groundwater have been reported in Indo gangetic plain (Handa, 1986). He also showed that in and around areas of high urbanization and industrialization, municipal and industrial wastes may contribute high levels of nitrate to the ground waters. Research over the last decade has clearly revealed that agriculture is the most important source of nitrate in the groundwater and surface water. Farid et al. (1993) has reported 75 mg/l NO_3 concentration in domestic wastewater irrigated area. Gallegos et al. (1999) reported of elevated nitrate concentration in wastewater irrigation site at Mexico. The study also shows that the COD of the groundwater in 30 years effluent irrigated field was quite high (30 mg/l) reflecting the high organic content of the groundwater in the effluent irrigated area.

The average percentage recoveries for organochlorine pesticides varies from 70 to 105% and results were not corrected for percent recoveries. The results of the analysis of organochlorine pesticides in the groundwater samples of the effluent irrigated area with respect to different period of irrigation are also given in Table 2. From this it is evident that, only α-HCH and β-HCH isomers were found in the groundwater samples and other organochlorine pesticides such as endosulfan, DDT, endrin, heptachlor and dieldrin were not detected. Variation in the concentrations of α-HCH and β-HCH with respect to the irrigation period is presented in the Fig.3. It could be found that the concentration of α-HCH and β-HCH increases with the period of irrigation. In water samples collected from more than 30 years, α-HCH and β-HCH were 18 and 67 ng/l, whereas, in 18 years effluent irrigated field, they were 17 and 15 ng/l and in 15 years effluent irrigated field, the concentrations were 14 and 10 ng/l respectively. In 12 years effluent irrigated field, no pesticides was detected. Solubility of α, β and γ isomers of HCH are 1.63 mg/l, 0.70 mg/l and 10 mg/l respectively. Among various isomers of HCH, γ-isomer is most soluble in water followed by α-isomer but as far persistency in the environment, β-isomer is the most persistent isomer

Table 2. Physico-chemical parameters, organochlorine pesticide residues and heavy metals in groundwater of paper mill effluent irrigated area.

PARAMETER	30 years (GI)	18 years (OPLIS)	15 years (OMLIS)	12 years (KLIS)
Physico-chemical				
pH	7.82	7.82	7.59	7.58
EC (dS/m)	1.87	1.44	1.38	1.38
TAN (mg/l)	0.244	0.289	0.240	0.246
NO_2-N (mg/l)	0.022	0.019	0.018	0.018
NO_3 (mg/l)	40	20	18	9
PO_4-P (mg/l)	bdl	bdl	bdl	bdl
Total P (mg/l)	bdl	bdl	bdl	bdl
COD (mg/l)	35	13	8	4
Pesticide residues (ng/l)				
α-HCH	18	17	14	bdl
β- HCH	67	15	10	bdl
γ-HCH	bdl	bdl	bdl	bdl
Heptachlor	bdl	bdl	bdl	bdl
Aldrin	bdl	bdl	bdl	bdl
Dieldrin	bdl	bdl	bdl	bdl
Endrin	bdl	bdl	bdl	bdl
Endosulphan	bdl	bdl	bdl	bdl
DDT	bdl	bdl	bdl	bdl
DDE	bdl	bdl	bdl	bdl
Heavy metals (mg/l)				
Cu	0.032	0.030	0.027	0.028
Cd	0.015	0.011	0.009	0.007
Pb	0.183	0.122	0.074	0.17
Zn	0.001	0.002	0.001	0.003
Cr	0.02	0.026	0.038	0.005

bdl – below detection level
OPLIS -- Odapalli Papanpalayam Lift Irrigation Scheme
OMLIS -- Odapalli Mukuparai Lift Irrigation Scheme
KLIS -- Kattur Lift Irrigation Scheme
GI -- Gravity irrigation

and γ-isomer is least persistent. The presence of only α and β-isomers in water samples collected from the effluent irrigated areas suggested no recent input of HCH in the effluent irrigation fields and it might be persisting due to its higher persistence and water solubility. Ramachandran et al. (1991) also has reported 576.1 ng/l of HCH in the irrigated areas of north Madras.

The heavy metal concentrations in the groundwater samples of the effluent irrigated area with respect to irrigation period are also given in Table 2. The concentration of copper and zinc content in the ground water ranges from 0.028-0.032 mg/l and 0.001-0.003 mg/l respectively. Heavy metal presents in the soil seep into nearby groundwater and contaminate it. The copper and zinc are the micronutrients required for plant growth. Though farmers apply zinc as the micronutrients for the paddy field in the effluent irrigation area the study shows that leaching was not there as the zinc content is very less in the ground water. The cadmium, lead and chromium content ranges from 0.007-0.015, 0.074-0.183 and 0.005 to 0.038 mg/l respectively. Thus the study reveals that the values were very less as compared to the groundwater quality in Naini industrial area, Allahabad, where, cadmium, lead and zinc were in the range of 0.083 to 0.054, 0.517 to 0.923 and 0.325 to 1.025 mg/l/ respectively. (Mohan et al. 1998).

It can be concluded from the present study that the period effluent irrigation has slightly influenced the nitrate accumulation in the ground water but it is well within the permissible level. Though, there is slight accumulation of heavy metals with the period of continuous irrigation with the paper mill effluents, they are well within the permissible limit. Moreover the levels of HCH in ground waters of effluent irrigated field were found to be negligible in proportion and it is safe for irrigation. Presence of only α-HCH and β-HCH in the 25 years and 15 years effluent irrigated field and not in the 12 years effluent irrigated field indicated that there was no recent input of HCH to the irrigated fields. In conclusion, we found that the concentration of nitrate, organochlorine pesticides and heavy metals reported in ground waters of effluent irrigated area in Tamil Nadu is relatively very low and it is unlikely that the residues will pose any health risk to farmers. However, monitoring program should continue in the effluent irrigated area.

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