The districts chennai, Chengalput, South Arcot and Erode did exhibit any wet years of the study period taken, while the other districts were with wet years from one to two.

Out of the five years of El-Nino (strength not indicated) the districts Chennai, Chengalput, and Thanjavur had rainfall more than normal in four years (or) in 80 per cent of El-Nino years, while in 40 per cent of El-Nino years of study the above normal rainfall was recorded in the districts of South Arcot, Salem, Trichy, Pudukkottai, Ramnad, Tirunelveli and Nilgiris. Madurai, North Arcot, Dharmapuri and Coimbatore districts fell under 60 per cent of El-Nino years with above normal rainfall category. In respect of La-Nino years the districts Chennai and Madurai did have NEM rainfall more than above normal in 12 years out of 20 La-Nino years of study. This was followed by Thanjavur and Ramnad. In 9 years out of 20 years of La-Nino years the districts Chengalput, Tirunelveli, Kanyakumari and Nilgiris had above normal rainfall. The least was with Erode and Pudukkottai districts. In the case of strong El-Nino year of 1982, except Madurai district, all district had shown negative departure from the NEM rainfall, which needs scientific probing.

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Accumulation and availability of Zn, Cu, Mn and Fe in soils polluted with paper mill waste water

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Abstract : Field experiments were conducted at M/s Sun Paper Mill Farms, Cheranmahadevi during Kar and Pishanam seasons, 1995-96. The treatments included three different irrigation sources and three soil amendments with rice ASD36 as test crop. Soils irrigated with paper mill waste water increased the pH and EC in both the seasons. Gypsum was better in lowering pH than rice husk ash whereas for EC the rice husk ash proved better. DTPA extractable Zn, Cu, Fe and Mn largely accumulated in the upper 15 cm soil depth and the extent of their accumulation was increased with increased time of application. Application of rice husk ash proved significant in preventing the micronutrients from reaching toxic levels in soils. *(Key Words : Paper mill waste water, Amendment, Gypsum, Rice husk ash, DTPA Micronutrients).*

Heavy metals tend to accumulate in soils and plant in undesirable amounts and proportions as a result of disposal of paper mill effluents on soils Some of these elements are useful in low concentrations, but inhibitory in high concentrations whereas others have an overall toxicity effect on plants. Paper mill waste waters are often used for irrigating crops on certain farms located near industries. Although in many instances, the use of paper mill waste water has favourably influenced crop production, its continuous application for a number of years resulted in enrichment of heavy metals in top layers of the soil. To lessen the deleterious effects of paper mill waste water application, the use of a suitable amendment, prior to its disposal, is generally recommended. However in India and in many developing countries, paper mill waste water is used as such for irrigation purposes. The practice is likely to result in an accumulation of even the essential micronutrients in soil to such levels which affect plant growth and availability of each other. The present study was undertaken to explore the effect of the continuous use of paper mill waste water over a period of two seasons on the accumulation of Zn, Cu, Fe and Mn in soil.

Materials and Methods

Field experiments were conducted with rice ADT 36 during Kar (June - August) and Pishanam (November - February) crop seasons of 1995-96 at M/s Sun Paper Mill Farm of Cheranmahadevi with three irrigation sources viz., irrigation with good quality water (M_1), 1:1 diluted effluent (M_2) and undiluted effluent (M_3) and three soil amendments viz., normal NPK application at 120:60:60 kg ha^{-1} (S_1), rice husk ash (S_2) and gypsum (S_3) at 12.5 t ha^{-1} In all, there were 9 treatment combinations tried in split plot design replicated thrice. Soil samples were drawn with stainless steel tube auger at increments of 0-15 cm depth. The samples were air dried and ground to pass through 0.5 mm sieve. Soil samples were analysed for pH and EC by standard procedures. Available micronutrients, viz., Zn, Cu, Mn and Fe in soil samples were estimated by DTPA methods (Lindsay and Norvell, 1978).

Results and Discussion

Some characteristics of the soils are presented in Table 1.

The pH of the surface soils of the fields irrigated with undiluted effluent (M_3) as well as 1:1 diluted (M_2), being on par recorded, a marked increase over that of good quality water irrigation (M_1). Soil amendments proved significant only at tillering stage of rice during Pishanam season. Rice husk ash application recorded higher pH value (7.50) and was on a par with normal NPK application (7.42). Similar trend was seen at maturity during both the seasons related to soil amendment. A general increase in the soil pH from an initial value of 7.30 to a range of 8.07 to 8.12 was observed. It was more than one unit exhibiting a tendency to change towards alkalinity which might be due to submergence under which the experiment was conducted and as was observed by Ponnam Peruma (1977). The increase in soil pH due to effluent irrigation might be attributed to the addition of alkaline earth metals like Ca, Mg and alkali metals like Na which are present in the effluent water in higher proportion. Similar results of increased soil pH due to paper mill effluent irrigation have been reported by Palaniswami (1989), Pushpavalli (1990) and Arunugam (1994).

There was a reduction in pH in plots treated with gypsum, which might be attributed to the release of Na from the exchangeable complex by Ca from the gypsum. However, such a reduction was not noticed in plots treated with rice husk ash. Rice husk ash being an organic amendment, the decomposition and release of Ca from it might be slow and hence it could not reduce the rise in the pH due to effluent irrigation.

In both the seasons (Kar and Phshanam) application of gypsum recorded markedly higher value for EC over rest at tillering and maturity stage whereas during Pishanam the undiluted effluent irrigation (M_3) recorded higher EC over rest of the treatments which were comparable among themselves. Similar results were obtained at maturity during Pishanam seasons. In the interaction of the irrigation sources with soil amendments, the superiority of the gypsum in increasing the soil EC could be seen only under the use of good quality water and 1:1 diluted effluent while in the case of undiluted effluent none of the soil amendments had any effect on soil EC.

The increase in the soil EC, in both the seasons due to effluent irrigation, is attributed to the addition of considerable quantity of dissolved salts through the effluent. The significant contribution of undiluted effluent in recording higher EC in soil was due to its increased salt contents which had the highest EC of 3.0 dSm^{-1}. The increase in soil EC due to paper mill effluent irrigation was also reported by Juwarkar and Subrahamanyam (1987) and Arumugam (1994). The addition of rice husk ash decreased the EC over the control and this might be due to its effect in improving physical properties of soil and thereby all the salts might be leached down to lower layers. At the same time, the addition of gypsum increased the soil EC over that of control. The dissolution and disassociation of Ca^{2+} and SO_4^{2-} from gypsum might have accounted for an increase in the EC in plots treated with gypsum.

The content of DTPA extractable Zn, Cu and Fe was the highest in soils irrigated with undiluted effluent irrigation, followed by 1:1 diluted effluent and good quality water. These results were presented in Table -2 and 3. Among the soil amendments tried, normal NPK application and gypsum were found to be comparable with each other recording higher soil available Zn, Cu and Fe over the rice husk ash in Kar and Pishanam seasons respectively.

In case of Mn, undiluted effluent irrigation recorded the highest value over the rest of the treatments tried. This trend was observed in both the seasons at both tillering and maturity stages.

In the interaction effect, undiluted and 1:1 diluted effluent were comparable with each other in the normal NPK applied plot. In the case of S at M interaction, the normal NPK was on par with rice husk ash and gypsum application, under good quality water and 1:1 diluted effluent irrigation whereas in undiluted effluent irrigation, normal NPK application registered higher soil available Mn over gypsum and rice hush ash application. During Pishanam, at tillering stage, undiluted effluent was comparable with 1:1 diluted effluent in normal NPK applied plot. Rice husk ash and gypsum were comparable with each other in good quality water treatment and 1:1 diluted effluent treatment Normal NPK application was significantly different for undiluted effluent irrigation.

At maturity in M at S interaction undiluted effluent and 1:1 diluted effluent were comparable with each other in the normal NPK applied plot while S at M interaction, all the three sub plot treatments namely control (normal NPK), rice husk ash and gypsum were comparable among themselves, in good quality water and 1:1 diluted effluent irrigation. In undiluted effluent, the normal NPK registered significantly higher soil available Mn than rice husk ash and gypsum applied plots. Similar trend was observed during Pishanam season also.

Irrigation with undiluted effluent has drastically increased the available micronutrient status (Zn, Cu, Fe and Mn) in soil over control. The increase in the concentration of these micronutrients in the surface soil layer has been resulted from the addition of these elements through the application of undiluted effluent. The increase in the organic matter content of the upper layer might have helped further to restrict their movement largely in the top soil. The results are in line with the findings of Bansal *et al.*, (1992).

A decrease in the soil available Zn, Cu and Fe due to rice husk ash application, in both the seasons, was observed which could be attributed to the improved physical properties of the soil such as permeability which leads probably to percolation of the above micro-nutrients to lower layers.

This study indicates that the continuous use of paper mill waste water for over one year results in the accumulation of DTPA extractable Zn, Cu, Fe and Mn in soil to levels that may cause imbalances of nutrients in the soil.

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Table 1. Soil characteristics in the surface soil layers

Treatment	pH				$EC (dSm^{-1})$			
	Kar		Pishanam		Kar		Pishanam	
	Tillering	Maturity	Tillering	Maturity	Tillering	Maturity	Tillering	Maturity
Mean								
M_1	7.23	7.65	7.13	7.59	0.68	0.65	0.67	0.52
M_2	7.74	7.90	7.46	7.76	0.57	0.92	0.80	1.08
M_3	7.75	7.11	7.55	7.73	0.71	0.92	1.05	1.17
S_1	7.57	7.08	7.42	7.86	0.45	0.66	0.58	0.84
S_2	7.59	7.31	7.50	7.96	0.56	0.60	0.50	0.62
S_3	7.57	7.12	7.24	7.27	0.90	1.23	1.43	1.32
CD(P=0.05)								
M	0.45*	NS	0.28*	NS	NS	NS	0.14**	0.49**
S	NS	0.23**	0.17*	0.42*	0.34*	0.28*	0.29**	0.60**

Table 2. Effect of irrigation treatments and soil amendments on soil available Zn and Cu

Treatment	Available Zn (ppm)				Available Cu (ppm)			
	Kar		Pishanam		Kar		Pishanam	
	Tillering	Maturity	Tillering	Maturity	Tillering	Maturity	Tillering	Maturity
Mean								
M_1	1.60	1.50	1.80	1.70	7.30	2.90	8.10	3.20
M_2	1.90	1.80	2.10	2.00	9.90	5.60	11.00	6.20
M_3	3.10	3.00	3.50	3.30	10.90	6.70	12.10	7.50
S_1	2.50	2.40	2.80	2.65	10.10	6.20	11.20	6.80
S_2	1.80	1.80	2.05	1.95	8.50	4.10	9.40	4.60
S_3	2.20	2.10	2.49	2.37	9.60	5.00	10.60	5.50
CD(P=0.05)								
M	0.28**	0.24**	0.28**	0.27**	0.67**	1.40**	0.76**	1.50**
S	0.32**	0.31**	0.36**	0.34**	1.06**	1.10**	1.17**	1.20**

Table 3. Effect of irrigation treatments and soil amendments on soil available Fe and Mn

Treatment	Available Fe (ppm)				Available Mn (ppm)			
	Kar		Pishanam		Kar		Pishanam	
	Tillering	Maturity	Tillering	Maturity	Tillering	Maturity	Tillering	Maturity
Mean								
M_1	14.2	10.3	15.7	11.4	16.8	12.2	18.7	13.6
M_2	21.5	17.1	24.0	17.9	23.3	18.7	26.0	20.8
M_3	31.5	27.3	35.0	30.4	30.3	25.6	33.7	28.5
S_1	24.1	20.0	27.0	21.2	23.3	18.7	26.0	20.7
S_2	20.6	16.2	27.0	18.0	22.5	17.9	25.0	19.8
S_3	22.5	18.5	25.0	20.6	24.6	20.0	27.0	22.3
CD(P=0.05)]								
M	4.9**	3.9**	5.8**	5.2**	1.6**	1.8**	1.8**	2.1**
S	1.6**	2.2**	1.7**	NS	NS	NS	NS	NS

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