Effect of Kraft Pulp Mill Effluents on Crop Performance and Soil Chemical Properties—Part I.

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ABSTRACT

Field scale experiments were carried out over a period of eight years to evaluate the crop performance and soil chemical properties under sustained irrigation with six dilutions of anaerobically treated kraft pulp mill effluent waste waters. Grain and dry matter yields under various irrigation water qualities were recorded and analysed. Soils were analysed to determine changes in chemical properties under cumulative irrigation with effluent. Results show that in light textured sandy loam soils sustained effluent irrigation does not produce any statistically significant differences in yield attern of wheat, barley and kusum. the three crops discussed in this paper. Soil Pariables have, however, shown changes in the occurrence level, but these have not affected the crop response over the period of investigation reported in the present paper.

INTRODUCTION :

Disposal of liquid effluents from industrial plants is a major problem that needs thoughtful planning and plan execution. It has to keep in constant view the possible health hazards and immediate or long term impact on surrounding biosphere. Liquid industrial discharges, if handled without appropriate techniques, tend to seriously affect water resources, both above ground and underground. In addition, the receiving media (e.g. soil) also face profound physico-chemical alteration due to accumulation of foreign chemicals and inert matter.

Land disposal of non-toxic industrial effluents has considerable economic potential if the disposal provides a perennial source of crop and tree irrigation. Viewed in national context it becomes more important where total agricultural land under regular irrigation is hardly 30 per cent and practically no forest or plantation area is under irrigation. It is hardly necessary to emphasize the need to begin irrigated for stry in India to increase the growth potential of limited forest resource with declining productivity.

Integrated pulp and paper manufacturing establishments are a major source of Waste Waters that can, to a great extent, provide additional irrigation capacity if suitable technology and methodology can be evolved for its utilisation. Manufacturing process followed in India allows for waste water discharge in the range of 230 to 260 cubic metres per ton of paper. A large pulp and paper plant producing around 200 metric tons of paper per day. thus, is responsible of discharging between 10 to 15 million gallons per day This means an irrigation capacity in the range of 45,000 to 50,000 cubic metres water every twenty four hours. Depending upon varying crop requirements of soil moisture for optimum growth and yield, this amount of water can cover agricultural forest lands in the range of 2000 to 10,000 hectares. This range covers land areas allocated for maximum water requiring crops like paddy to sustaining plantation trees like eucalyptus and poplars.

Efforts to utilise this potential have spanned over past fifty years with mill effluents the nature of which varied depending on the pulping process and nature of chemicals used in different processes. A detailed review of literature has been made by National Environmental Engineering Research Institute (N E E R I), Nagpur in "Utilisation of Pulp and Paper Mill waste waters for Agriculture (1979) (1 a) and in" A Bibliographical Review of Indian Literature" prepared by N E E R I

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and presented during International Seminar on Management of Environmental Problems in the Pulp and Paper Industry (1982) (1 b). Reference can be made to these publications for details. Select bibliography is presented below.

Sulphite pulp mill effluents produced no adverse effects on the germination and growth of sunflower seeds in a study carried out by Spulnik in 1940[2]. Stephenson and Bollen's 1949 studies with potato, corn, beans. cabbage. carrot, tomato etc showed satisfactory growth of all the studied crops under effluent irrigation[3]. Stuart and Crawford (1958) successfully grew corn, groundnut, soybean and other crops under irrigation with kraft mill waste waters[4]. Bishop and Wislon grew several species of grasses under kraft pulp mill effluent irrigation in 1954[5]. Jorgeman (1965) also used similar effluents to grow pines sucessfully[6]. Extensive studies were carried out by Mc Carmic with Kraft mill waste water Irrigation of cotton, corn, rice, and several fodder crops, between 1959 and 1965[7,8]. No adverse effect on growth and yield was reported by him. Nesterov (1968) even reported better performance of some vegetable and tree seedlings under effluent irrigation[9].

In India, where majority of pulp mills follow kraft pulping process, land disposal of effluents as irrigation water has also attracted attention of researchers. Khambatta and Ketkar (1977) have reported cultivation of sugarcane, paddy, wheat, vegetable and fruits with treated effluents irrigation[10]. Bhattacharyya (1975) reported increased rice yields by using paper mill sludge in coastal saline soils[11]. Rajannan and Oblisami (1979), however reported adverse effects of undiluted effluent irrigation on rice, blackgram and tomato seeds and seedlings[12]. Prasad et al (1977) have studied effects of anaerobically treated pulp mill effluents from germination stage to harvest stage and reported favourable crop response accepting a few sensitive crops like gram[13]. Reddy et al (1981) have studied the performance of sugarcane under effluent irrigation and have reported better cane yields compared to plain water irrigation[14]. Dubey and Pande (1980) have studied the soil chemical properties impregnated with kraft pulp mill effluents and have reported increased ionic activity in laboratory equilibrated soils[15].

The above review is indicative enough of the potentiality of the pulp and paper mill effluents as irrigation water to grow a variety of crops provided a carefully drawn methodology is available which keeps in view the long term effects on biospheric equilibrium and soil dynamics

Systematic studies, with above points of view in mind, were started by the Orient Paper Mills, Amlai, [M.P] Division in 1974 in collaboration with National Environmental Engineering Research Institute, Nagpur and since 1978 in collaboration with Birla Institute of Scientific Research Calcutta. In this papers observations and conclusions of eight years of field investigations on wheat and paddy are presented. In succeeding parts performance details of other agricultural and non-agricultural crops will be presented and discussed.

MATERIALS AND METHODS :

The Effluent :—The effluent used in the present investigations is called grade-3 effluent at the Orient Paper Mills' plant. It is deep brown in colour due to the presence of Sodium-ligno compounds and comprises of digester house leakages, wash liquors from the pulp mill and caustic extraction effluent from the bleach plant. Its initial high pH value of 10–10.5 is lowered to the level of 8–8.5 by addition of chlorination and hypochlorite effluent in the ratio of 3.5 : 1.

The final combined discharge, amounting to about 4.5 million gallons per day is stored in a lagoon after clarifloculation. The lagooned effluent is naturally treated anaerobically aided by organic and chemical fertilisers in a 28 days storage cycle.

The treated effluent is pumped to the experimental site through a 5 H.P. electric motor. Chemical analysis of the effluent used in various experiments is given in table-I. In the same table are given characteristics of plain water used in dilutions and the control treatment number 6 described later. For comparative evaluation ISI standardisation in respect of tolerance limit of industrial waste waters used as irrigation water is given in table-2

The Soil :—As a receiving and reacting medium the soil is an important factor for consideration. Soil reactions depend on its physical and chemical properties. The soils in experimental area are sandy loams with underlying clay belts. There are large patches of black clayey soils. Experimental blocks were laid out in both the distinct types. Analysis of typical sandy loam soils and clay soils of the experimental area is given in table-3.

Table-1
Average characteristics of the pulp mill effluent and plain water used in the field experiments.

Parameters	Treated effluent	Plain water
pH (1:2.5)	8.00	8.00
EC mmhos/cm. at 25°C	2.2	0.285
Calcium (meq/L)	2.5	1.51
Magnesium (meq/L)	0.3	0.7
Sodium (meq/L)	18.3	1.739
Potassium (meq/L)	0.4	0.051
Chloride (meq/L)	8.2	1.26
Carbonate (meq/L)	Nil	0.2
Bicarbonate (meq/L)	12.8	1.96
Sulphate (meq/L)	1.6	0.45
B.O.D. (mg/L)	187	Nil
C.O.D (mg/L)	1181	Nil
Total dissolved solids (mg/L)	2184	250
Suspended solids (mg/L)	148	30

Table-2
Tolerance limits for Industrial Effluents disposed on land for irrigation (IS: 3307-1965) (All values except pH and per cent Sodium are expressed as mg/L)

Parameters	Characteristics
pH	5.5-9.00
Total dissolved solids	2100
Sulphate (SO_4)	1000
Chloride (Cl)	600
BOD_5 20°C	500
Oil and grease	30
Boron (B)	2
Per cent Sodium	60
Radio active materials-	
Alpha emitters, μc	10-9
Beta emitters, μc	10-8

Table-3
Chemical caaracteristics of the virgin sandy loam soils before the commencement of effluent irrigation (Analysis year 1974)

Parameters	Average values
pH	6.5
Organic matter (%)	0.59
Exchangeable cations	
Calcium (meq/100 gm)	3.6
Magnesium (meq/100 gm)	1.6
Sodium (meq/100 gm)	0.32
Potassium (meq/100 gm)	0.57
Saturation extract analysis	
EC mmhos/cm. at 25°C	0.582
Calcium (meq/L)	3.7
Magnesium (meq/L)	0.3
Sodium (meq/L)	0.8
Potassium (meq/L)	0.7
Chloride (meq)/L)	1.7
Carbonate (meq/L)	Nil
Bi-carbonate (meq/L)	2.3

The irrigation treatments—To evaluate the affect of various levels of effluent concentrations on crop growth and yield performance and soil chemical characteristics following six dilutions of effluent were devised—

Treatment No	Irrigation water mix ratio	Percentage dilution
1.	Effluent 1 : Plain Water 0	100% effluent
2.	Effluent 2 : Plain Water 1	66% ,,
3.	Effluent 1 : Plain Water 1	50% ,,
4.	Effluent 1 : Plain Water 2	33% ,,
5.	Effluent 1 : Plain Water 4	25% ,,
6.	Effluent 0 : Plain Water 1	100% Water

Dilution ratio and volume of irrigant mixture were controlled by pre-mixing the effluent and plain water in specified quantities and then applying it to the plots with buckets. Volume of each irrigation treatment was equivalent to 2.5 acre inch. As the experiments were carried out in field conditions, the effect of natural precipitation was taken into account and irrigation treatment frequency was regulated to provide optimum soil moisture conditions required for individual crops.

The field design—Effect of irrigation water quality on crop growth and soil properties is gradual due to biospheric and atmospheric pressures striving continuously to achieve a state of equilibrium and hence evaluation period is considerably longer. The layout of the experiments has, therefore, been such as to follow a particular crop rotation in a particular plot from year to year under the same irrigation treatment.

In 1974-75 randomised block design experiments were laid out for the six irrigation treatments in three replication study. To facilitate manual operations involved in irrigation procedures the plots size was kept at square metres. Considering the nature of experiments, individual treatment plots were separated from each other by 45 c.m. wide channels to prevent lateral percolation of effluent dilutions which may result in spoilage of adjacent treatments. Records were maintained since the laying out of the experimental blocks showing the number of irrigations [the total volume] given to each plot. Simultaneous records of grain and dry matter yields and other parameters for each crop have also been maintained and compared from year to find the cumulative effect of irrigations water quality.

The Crops—A broad selection of both cereal and non-cereal crops were evaluated over the years. Summer and winter agricultural crops as well as perennial horticultural and forest trees, aromatic and medicinal shrubs and herbs have been included in the study programme.

Basic agronomic variables were followed as per the standard recommendations for each crop[16,17] like sowing time, tillage, sowing procedures, fertiliser doses and application and crop processing.

In the present paper response of two major cereals, wheat and paddy and one oil seed crop, kusum, has been reported. Studies on other crops will be reported in subsequent publications. Two varieties of wheat (HDM 1553 and HDM 1593) and two of paddy (Ratna and Kauvari) were grown in Rabi-Kharif rotation in the same experimental blocks between 1975 anh 1982, In one series of experiments the crop rotation has been maintained for the whole reported study period. In the second series, however, an oil seed crop, Kusum (Carthamus tinctorius), has been introduced from fifth year onwards to evaluate the response of a new crop in already effluent enriched soils (see table–4).

TABLE—4

Pattern of cropping and frequency of treatment irrigation (1975-1982)

Year	1975 K	1975-76 R	1976 K	76-77 R	1977 K	1977-78 R	1978 K	1978-79 R	1979 K	1979-80 R
Series A crops	Paddy Var. Ratna	Wheat Var. HDM 1553	Paddy Var. Ratna	Wheat Var.HDM 1553	Paddy Var. Ratna	Wheat Var. HDM 1553	Paddy Var. Ratna	Wheat Var.HDM 1553	Paddy Var Ratna	Safflower
Treatment irrigation Volume(A)	42.5 acre inch.	28 acre inch.	37.5 acre inch.	35 acre inch.	42.5 acre inch.	20 acre inch.	10 acre inch.	15 acre inch.	22.5 acre inch.	27.5 acre inch.
Series B crops	Paddy Var. Kaveri	Wheat Var. HDM 1593	Paddy Var. Kaveri	Wheat Var.HDM 1593	Paddy Var. Kaveri	Wheat Var. HDM 1593	Paddy Var. Kaveri	Wheat Var HDM 1593	Paddy Var. Kaveri	Wheat Var.HDM 1593
Treatment irrigation Volume(B)	42.5 acre inch.	35 acre inch.	46.5 acre inch.	37.5 acre inch.	42.5 acre inch.	22.5 acre inch.	10 acre inch.	17.5 acre inch.	22.5 acre inch.	25 acre inch.

Year	1980 K	1980–81 R	1981 K	1981–82 R	1982 K
Series A crops	Paddy Var. Ratna	Safflower	Paddy Var. Ratna	Safflower	Paddy Var. Ratna
Treatment irrigation Volume(A)	10 acre inch.	10 acre inch.	20 acre inch.	12 5 acre inch.	Nil
Series B crops	Paddy Var. Kaveri	Wheat Var. HDM 1593	Paddy Var. Kaveri	Wheat Var. HDM 1593	Paddy Var. Kaveri
Treatment irrigation Volume(B)	10 acre inch.	20 acre inch.	20 acre inch.	12.5 acre inch.	Nil.

soil analysis–At the beginning of the research project standard samples of virgin soil were drawn from the experimental plots and analysed in the laboratory. This formed the basis of comparative evaluation of charges in the soil composition as brought out in subsequent analyses of samples drawn at the end of each crop cycle.

Soil samples were drawn from each post harvest plot from upto a depth of 9 inches. The samples were shade dried and later analysed following standard analytical procedures[18,19]. Distilled water filtrate of the soils was analysed for electrical conductivity, Calcium, carbonate and bicarbonate. Exchangeable cations were determined by Ammonium Acetate Method. Flame photometer was also employed for the determination of Sodium and potassium. pH of the soils was determined with the help of pH meter.

Field data in respect of grain and dry matter yields and laboratory analysis data for various parameters were statistically analysed following Panse and Sukhatme[20].

RESULTS AND DISCUSSIONS :

A survey of table–4 shows two crop rotation patterns. In one (series A) rotation paddy of monsoon season was alternated with wheat in winters. This was altered after four years to accommodate a new crop (Kusum) in place of wheat. In the second (series B) rotation of paddy and wheat was followed throughout the period of experiments, using the same varieties Crop performance, evaluated in terms of grain and dry matter yields, is presented in tables 5,6,7, and 8.

Response of both the varieties of paddy (Ratna and Kaveri) and wheat (HDM 1553 and HDM 1593) has been non–significant on statistical scale for all the dilutions of irrigant effluent water. The observed variation in yields are attributed to extraneous factors and not the treatments. Year to year response of a variety appears to be greater on casual reading of the tables, but it can be observed that the percentage difference of various treatment's response is evenly distributed. The difference is, thus, not an effect of the cumulative effluent enrichment of the soil but a typical crop response to the particular year's climatic pressures. In low yield years (i.e.1976 and 1979, see table–5) the crop in all the treatments has given lower values, compared to preceding or following years. Even in normal crop cultivation in average nutrient level soils (as of this area) the yields tend to taper off after continuous cropping over the years and rejuvenation practices like green manuring or a season's break in cultivation or heavy fertilisation etc are recommended. Effluent irrigated crops of wheat and paddy in light textured sandy loam soils have behaved like normally irrigated crops.

Oil seed crop of Kusum has also yielded without any significant variation under various irrigation treatments in all the three years of its cultivation in plots vacated by paddy. Being a winter season crop, when natural rainfall is below average in the region and main source of moisture has been the treatment irriga. tion, it has adapted satisfactorily to the effluent.

Soils—Laboratory analysis results of both the series of experiments at two stages (1978 and 1983, after fourth and eighth years) are reported in tables 9 and 10. These tables should be read along with the tables 3 showing the original state of the soil before experimental irrigation with the effluent.

Also, to understand the soil reaction to continu- irrigations with the effluent year after year a reading of table—4 will help where volumes of irrigations are recorded for each cropping season. It can be noted that while in initial years the total volumes of irrigation are on the higher side, in later years there is applied a lower total volume and season before the last reported crop no treatment irrigation has been given. The last cropping has, thus, allowed for natural leading down of so far accumulated ions in the soils.

A comparision of the soil analysis tables shows that pH value has risen in all the treatments, more so in the higher effluent concentrations. pH increase in the case of plain water irrigated plots is due to the presence of alum which is used in the water treatment plant and whose spoilage has been used for irrigation experiments (table—1). Organic matter contents of effluent irrigated soils have increased (from 0.59 percent to 1.30 percent, table-9) more significantly than in plain water or lower effluent dilution receiving soils. This is understandable because of the high lignin and TDS contents in the effluent. Electrical conductivity in the virgin, uncropped soils was 0.582 in 1974 which has gone up by 300 to 400 per cent in eight years in pure effluent irrigated soils in comparision to plain irrigated soils where the rise in EC is only about 100 per cent. Higher

TABLE—5

Yield characteristics of paddy variety Ratna, under effluent irrigation.

Effluent:	1975		1976		1977		1978		1979		1980		1981		1982	
Water	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg
1:0	1.166	1.256	0.850	1.033	1.466	1.650	1.333	1.266	0.373	0.966	1.173	1.273	0.573	0.716	0.830	1.550
2:1	1.083	1.416	0.783	0.916	1.500	1.633	1.583	1.250	0.621	0.800	0.960	1.166	0.543	0.670	0.783	1.166
1:1	1.166	1.250	0.850	1.016	1.550	1.583	1.416	1.183	0.800	0.840	0.833	1.116	0.510	0.716	0.916	1.416
1:2	0.916	1.500	0.916	1.166	1.716	1.533	1.583	1.500	0.833	1.100	1.193	1.250	0.496	0.783	0.883	1.483
1:4	1.166	1.283	0.683	0.900	1.666	1.533	1.250	1.316	0.620	0.900	0.823	1.066	0.450	0.750	0.866	1.466
0:1	1.010	1.250	0.916	1.050	2.050	1.733	1.466	1.350	0.720	0.966	0.966	1.116	0.606	0.833	0.890	1.566
CD 1%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N. S.	N.S.	N.S.
CD 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N. S.	N.S.	N.N.

TABLE—6

Yield characteristics of wheat variety HDM 1553 and Kusum under effluent irrigation.

	Wheat HDM 1553		Wheat HDM 1553		Wheat HDM 1553		Wheat HDM 1553		Kusum		Kusum		Kusum	
Effluent:	1975		1976		1977		1978		1979		1980		1981	
Water	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg	Grain kg	Dry matter kg
1:0	0.993	1.083	1.083	1.433	1.066	1.066	1.016	1.433	0.406	0.633	0.236	0.583	0.270	0.593
2:1	0.670	0.866	1.183	1.366	0.066	1.266	1.166	1.300	0.433	0.693	0.246	0.483	0.300	0.550
1:1	0.823	0.953	1.150	1.316	1.100	1.566	1.066	1.016	0.420	0.533	0.320	0.666	0.333	0.493
1:2	0.703	1.223	1.200	1.250	1.100	1.566	1.166	1.133	0.306	0.620	0.233	0.526	0.306	0.516
1:4	0.896	0.903	1.250	1.383	1.166	1.600	1.183	1.000	0.413	0.746	0.290	0.583	0.406	0.560
0:1	0.643	0.746	1.183	1.416	1.033	1.300	0.800	1.083	0.433	0.586	0.236	0.466	0.356	0.493
CD 1%	N.S	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S
CD 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

TABLE—7

Yield characteristics of paddy variety kaveri under effluent irrigation.

Effluent: water	1975 Grain kg	1975 Dry matter kg	1976 Grain kg	1976 Dry matter kg	1977 Grain kg	1977 Dry matter kg	1978 Grain kg	1978 Dry matter kg	1979 Grain kg	1979 Dry matter kg	1980 Grain kg	1980 Dry matter kg	1981 Grain kg	1981 Dry matter kg	1982 Grain kg	1982 Dry matter kg
1:0	1 083	1.125	0.760	1.233	0 933	1.333	1 000	1.200	0.313	0 773	0.740	0 966	0.850	0 866	0.853	1 32
2 1	1.166	1.500	?.716	0.900	1.250	1.433	1.000	1.350	0.446	0.766	0.826	1.056	0.750	0.800	0 8:0	1.466
1:1	1.250	1.433	0 753	0.966	1.000	1.316	1.000	1.166	0.460	0.796	0.809	0.983	0.766	0.700	0 920	1.666
1:2	1.291	1.666	0.633	0.833	1.116	1.033	1.000	1.000	0 613	0.930	0 623	1.033	0.466	0.633	0.796	1 380
1:4	1.5 0	1.833	0.775	1.100	1 233	1.500	1.000	1.033	0.376	0.706	0.886	1 020	0.7:0	0.7?3	0.846	1.416
0:1	1.325	1 716	0.666	0.900	1.366	1.333	0.916	1.250	0.353	0.633	0.746	0.946	0.566	0.683	0.833	1.053
CD 1%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N S.	N.S.	N.S	N.S.	N S.	N.S.	N.S.	N.S.	N.S.
CD 5%	N S.	N.S.	N.S.	N S.	N S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N S.	N.S.	N.S.

TABLE—8

Yield characteristics of wheat variety HDM :593 under effluent irrigation.

Effluent: water	1975 Grain kg	1975 Dry matter kg	1976 Grain kg	1976 Dry matter kg	1977 Grain kg	1977 Dry matter kg	1978 Grain kg	1978 Dry matter kg	1979 Grain kg	1979 Dry matter kg	1:80 Grain kg	1:80 Dry matter kg	1 81 Grain kg	1 81 Dry m tter kg
;	0.983	0.866	1.466	1.233	1.166	1.000	1 266	1.966	1.136	0 633	0 740	0.473	0.786	0.753
:1	1.030	0.796	1.583	1.433	1.066	0.766	1.166	1.563	1.096	0.600	0.753	0.483	0.640	0.766
1:1	1 010	0.850	1.666	1.233	1.66	0.666	1.166	1.666	1.053	0.600	0.733	0 443	0.683	0.753
1:2	1.116	0.883	1.483	1.433	1.183	0.816	1.100	1.566	1.066	0.623	0.750	0 500	0.766	0.850
1:4	0.953	0.840	1.533	1.266	1.233	0.766	1.066	1.466	1.066	0.666	0.750	0.506	0.790	0 793
0:1	0 970	0.853	1.400	1.500	1.300	1.366	0.983	1.350	0.966	0.566	0.866	0 476	0.736	0.937
CD 1%	N.S.	N S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
CD 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

TABLE—9

Chemical properties of soils of series A cropping under effluent irrigation.

Effluent : plain water	Year	pH 1:2.5	Organic matter %	Exchangeable cations (meq/100 g/m. soil) Ca++	Mg++	Na+	K+	Analysis of saturation extract ECX10³ at 25°C	Ca++ (meq / L)	Mg++	Na+	K+	Cl−	$CO_3^{=}$	HCO_3^-
1 : 0	1978	8.4	0.68	3.6	0.3	1.8	0.3	2.1	4.8	0.3	18.0	0.5	9.3	Nil	8.0
	1983	8.0	1.30	7 9	—	0.5	0.3	1.6	6.9	—	4.5	0.3	10.0	Nil	5.6
2 : 1	1978	7.9	0 66	3.3	0.4	1.5	0 4	1.5	4 5	0.4	13.0	0.5	7.6	Nil	6.0
	1983	7.9	0.55	7.1	—	0.5	0.3	1.2	5.5	—	4.3	0.2	9.3	Nil	4 6
1 : 1	1978	7.4	0 66	4.4	0.6	1.1	0.4	1.5	4.0	0.5	12.0	0.5	6 3	Nil	4.6
	1983	7.9	0.65	7 0	—	0 4	0.4	1 0	5.5	—	3.9	0.3	7.0	Nil	4 6
1 : 2	1978	7.3	0.60	4.2	0.5	1.1	0.4	1.5	5.0	0.5	10.0	0 8	6.3	Nil	5.0
	1983	7.8	0.97	6.2	—	0.4	0.5	1.6	5.4	—	3.8	0.4	7.0	Nil	6.0
1 : 4	1978	6.9	0.60	4.3	0.4	1.0	0.5	1.3	5.0	0.5	8.6	0.8	5.6	Nil	4.0
	1983	7.8	0.58	6.7	—	0.3	0.5	1.4	6.00	—	3.1	0.2	6.5	Nil	5.0
0 : 1	1978	6.6	0.59	5.0	0.6	0.6	0.6	1.0	3.5	0.6	5.0	0.8	3.3	Nil	4.0
	1983	7.6	0.60	5.2	—	0.3	0.5	1.2	5.0	—	2.6	0.4	5.3	Nil	5.0

TABLE—10

Chemical properties of soils of series B cropping under effluent irrigation

Effluent : plain water	Year	pH 1:2.5	Organic matter %	Exchangeable cations (meq/100 g/m. soil) Ca++	Mg++	Na+	K+	Analysis of Saturation extract EC×10³ at 25°C	Ca++ (meq / L)	Mg++	Na+	K+	Cl−	$CO_3^{=}$	HCO_3^-
1 : 0	1978	8.0	0.75	3.4	0.0	2.1	0.2	2.3	4.3	0.0	21.5	0.2	11.3	Nil	8.6
	1983	7.9	1.20	6.6	—	0.5	0.3	2.6	8.5	—	7.3	0 4	14.0	Nil	7.6
2 : 1	1978	8.0	0.71	4.4	0.0	2.1	0.5	1.9	4 3	0.2	16.2	0.3	5.3	Nil	9.0
	1983	7.6	1.10	5.5	—	0 4	0.3	1.7	7.4	—	4.9	0.4	9.3	Nil	7.0
1 : 1	1978	8.0	0 68	4.3	0.0	1.6	0.5	1 6	3.5	0 2	14.0	0.5	5.6	Nil	4.6
	1983	7.4	0.75	6 8	—	0.4	0.4	1.5	7.0	—	4.4	0.3	8.0	Nil	5.6
1 : 2	1978	7.8	0.63	4.6	0.2	1.3	0.5	1.3	5.2	0.3	11.0	0.3	6.0	Nil	6 0
	1983	7.6	0.80	5 8	—	0.3	0 4	1.2	6 6	—	3.4	0.3	8.0	Nil	5.6
1 : 4	1978	7.6	0.60	3.6	0.3	1.0	0.5	1 3	4.0	0.5	10.0	0.3	5.7	Nil	5.6
	1983	7.6	0.80	5.0	—	0.3	0.5	1.3	6.0	—	3.2	0.2	7.3	Nil	6.0
0 : 1	1978	7.0	0.60	3 9	0.3	0.6	0.5	0 8	3.1	0.5	6.0	0 3	2 8	Nil	4 0
	1983	7.5	0.75	5.9	—	0.3	0.5	1.3	6 7	—	3.2	0.2	6 6	Nil	5.0

ionic built-up in the effluent water is responsible for this soil reaction.

Balance of various ions in the effluent irrigated soils has shown appreciable fluctuation while the status of potassium has remained more or less unaffected over the years, the magnesium level has shown a tendency towards depletion in higher effluent concentration after 1978 cropping. This could not be verified in the currently discussed two (A and B) series of experiments, but is being investigated separately. It is, however, noticed that the crops have shown no magnesium deficiency symptoms.

Distinct increases can be seen in the levels of Sodium, Calcium, chloride and bi-carbonate ions in concentrated effluent irrigated soils compared to plain water or diluted effluents. It can, however, be noticed that with decreasing volume of irrigation waste water in later four years of the experiments the levels of Sodium have tended to come down sharply. Build up of Calcium, chloride and bicarbonate ions, however, has not shown such a tendency.

CONCLUSIONS

Present series of experiments, covering eight years and sixteen cropping cycles, has indicated positive potential of anaerobically treated kraft pulp mill effluents diluted with chlorination effluent as a source of irrigation to grow wheat and paddy crops. On statistical scale the yields were equal under plain water and effluent irrigations. No adverse affects have been noticed on morphology of the plants. Varietal response within the crops has also been insignificant. In the soil system some changes in the balance of ions has been noticed. Levels of Sodium, Calcium, chloride and bicarbonate have shown upward trend in pure effluent enriched soils, but their levels are far below the standard tolerance limits (e.g. table—2). Also the crops studied here have shown good adaptation to this new ionic balance. A tendency that has been noticed is that in light textured sandy loam soils the ionic balance starts coming down towards normalcy with decreased frequency of irrigation (assisted by leaching due to natural precipitation, e.g. monsoon rains).

A pattern of cropping with corresponding management of soils can be devised for optimum benefit from effluent irrigation. This will be discussed in the final and concluding part of these investigations.

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