IRRIGATIOINAL UTILISATION OF PULP & PAPER MILL WASTE WATERS AT ORIENT PAPER MILLS, AMLAI (M.P.)

BY

Pande M.C.*, Joshi R.C.**, Khare Alok** and Singh, M.M.**

INTRODUCTION

Production of wastes is an inevitable consequence of industrial processing. In other words industrial wastes symbolise technological progress and development. In a developing society industrial progress and waste generation are unavoidable. The question is how the pace of development can be maintained and accelerated without equivalent waste becoming a social or environmental liability. Most of the important industries produce wastes of some kind in variable quantity. Development of appropriate technologies to manage these wastes is a major con cern of research and development activities throughout the world.

Paper industry, like many others, has not remained untouched by the malaise of waste production and its proper management. To produce one ton of paper it has to utilise anywhere upto one hundred thousand gallons of water, most of which comes out as an industrial effluent, which though non-toxic, is, nevertheless, an aesthetic pollutant of river water resources. Nearly one third of the effluent discharge carries in it non-biodegradable ligno compounds rendering it brownish in colour. It has above normal levels of alkalanity and poor oxygen contents. Characteristics of this effluent are given in Table No. 1. At Orient Paper Mills, Amlai (M.P.) this effluent is broadly termed as Grade-III effluent which consists of brown stock washwater, digester house spills and leaks, chemical recovery section waste-waters and caustic extraction stage wastewater from bleach section and diluting quantities of chlorination and hypochlorite bleach wastewater. Total quantity of this combined effluent is nearly 4.5 million gallons each day.

* Birla Institute of Scientific Research, Amlai (M.P.)

** Orient Paper Mills, Amlai (M.P.)

This condominium of effluents undergoes a systematic treatment both under aerobic and anaerobic conditions. Despite this high cost treatment the aesthetic pollutant quality remains in the treated effluent.

Discharge of this effluent in the river results in slight discolouration of river water. Only economical solution to this problem is alternate discharge on land which is an excellent absorbent. Considering the non-toxic nature of effluent the land disposal can profitably be linked to crop irrigation. It is, thus, possible not only to prevent river water pollution but also to augment already scarce irrigation water resources of the nation where nearly 70 per cent of the cultivated land depends solely on natural precipitation.

Over past twelve years investigations carried out at Orient Paper Mills, Amlai have conclusively shown that the mill effluents can be used to irrigate on large number of agricultural and forest tree crops. This paper sums up the findings of the investigations carried out at the Mills in collaboration with National Environmental Engineering Research Institute, Nagpur (1974-78) and Birla Institute of Scientific Research (1978- continuing).

MATERIAL AND METHODS:

As indicated in the introductory section the effluent with major pollution potential is brown coloured grade-3 effluent. Its pre-treatment and post-treatment characteristics are given in Table No. 1. During field investigations the pre-treatment effluent has been used for irrigating more tolerant forest tree plantation species. Eucalyptus hybrid. The post-treatment effluent is being used for experimental irrigation of a number of cereal, fodder, annual and biennial cash crops and perennial fruit trees. A list of crops grown over the years is given in Table No.2.

Soils, being the primary absorbing medium for the effluent waters were carefully selected to represent various soil formations to be found in the experimental area. In Amlai region the soils are mostly sandy loams wirh scattered pockets of clay loams, black cotton soils and sandy clays. Two types of soil formations have been taken up for field experimentation -

Type A - Light textured sandy clays with greater porosity and lesser water retention capacity.

Type B - Heavy textured clay loams with lesser porosity and greater water retention capacity.

Field investigations on irrigational utilisation have been carried out through two series of experiments -

Series 1 - Periodic flood irrigation of 30 acres of Eucalyptus plantations in type A soils, with raw untreated effluent.

Series 2 - Controlled irrigation of micro-plots in randomised block design experiments growing annual and perennial cereal and cash crops plots are laid in both type A and Type B soils. For irrigation anaerobically treated effluent is being used in various dilutions with plain water. Six dilutions have been used ranging from 100 per cent pure effluent to 100 per cent pure water.

During 1978-1986 period average quantities of effluent irrigation for major groups of crops have been as follows:

1.	Eucalyptus hybrid	- 425 acre feet per year.
2.	Rabi cereals (wheat, barley, oats etc)	- 15 acre feet (Nov.-March).
3.	Kharif cereals - Paddy	- 30-40 acre feet (July-October).
4.	Kharif cereals (maize, Jowar, bajra etc)	- 10 acre feet (June-October)
5.	Perrennial cash crops (banana, coconut etc)	- 90-100 acre feet per year
6.	Sugar cane	- 50-60 acre feet (March-November).

Irrigation water quantities listed above have been found to be sufficient to maintain optimum soil moisture regime specified for each crop under tropical conditions.

For annual agricultural crops grown in micro-plot experiments regular data have been collected for grain and dry matter yields. Post-harvest soil samples are also collected and analysed for physico-chemical characteristics.

For raw effluent irrigated Eucalyptus 15 year old stems in experimental strips were removed after 8 years of continuous irrigation during which the 30 acre plantation block received 3400 acre feet effluent irrigation which is equivalent to nearly 960 million gallons. Yield and wood characterisation, pulp and paper making qualities and post-felling soil characteristics were determined.

RESULTS AND DISCUSSIONS:

Experimental details of various experiments and results in respect of some soils and annual agricultural crops have been published(1,2,4 and 5). Similar details in respect of Eucalyptus hybrid are under publication(3). Results for all other crops are being computed and published in a series of papers as parts of (1) above. In this communications from the published and to be published results.

Soil is an extra-ordinary medium of absorption and filteration specially when it is in a light textured formation. Lysimeter studies conducted by NEERI at Orient Paper Mills, Amlai have revealed that a two meter deep soil profile can remove the colour of effluent from percolates as well as reduce the BOD and COD loads to almost zero level. In natural regularly cultivated fields excessive discharge of effluents as irrigant, is, therefore, unlikely to disturb the underground water qualities, as the nature's soil system goes several meters more deeper than the aritificially erected soil profile of a lysimeter. This is an important consideration when planning for heavy flood irrigation of forest tree plantations by the mill effluents.

Irrigation of soils to grow crops leads to a continuous adjustment of various ions present in the soil medium. Characteristics of the irrigation water naturally affect this process of adjustment and balancing. Paper mill effluents carry a reasonably high load of chemicals, which, when intermixed with the already existing soil chemical environment, result in greater soil chemical activity. Comparative study of Table 1 shows the levels of various parameters in the effluent in comparison to plain water. Special noticeable are the much higher levels of sodium, chloride and bicarbonates in the effluent.

In Table No.3 weighted averages are given for various parameters studied in virgin soils and the same soils after sustained effluent irrigation for 10 years. As expected, soil alkalinity has tended to increase in both types of soils, more so in heavy textured soils due to their relatively higher capacity to bind free ions. Organic matter level has increased due to build up of organic suspended solids present in the irrigant effluent. Build up in the level of various ions is also obvious. Increased electrical conductivity of the irrigated soils can be attributed to this salt accumulation. In heavier soils the increase in EC is proportional to their greater capacity of salt retention. Leaching property and capacity of the soils, therefore, are important considerations in deciding what type of soils should be used for growing crops under effluent irrigation.

Response of various crops to effluent irrigation is given in Table 4. Most of the crops studied so far have shown remarkably good tolerance to the effluent. In fact, during initial period of irrigation higher yields were obtained in effluent irrigated plots over the plain water irrigated ones. In subsequent cropping cycles, however, there is slight reduction or equillibrium in the yields, which, however, has been found to be statistically insignificant. Ability of certain crops to tolerate high levels of salt accumulation in the soils has also come out during the investigations. Barley, oats, sugarcane, safflower and some others have been found to be more tolerant than wheat, paddy and maize while most of the pulse crops like gram, moong, urid and arhar have shown relatively poor tolerance to pulp mill effluents. Among green fodder crops, perrennial grasses like napier grass have yielded consistently, annual fodder crops like barseem and lucerne have given decreasing yields after 4-5 years of sustained irrigation with effluent. Fibre crops like kenaf, reselle and sunn-hemp have also given better and consistent yields in comparison to normally irrigated condition.

Gradual built up of salts in the soils has been found to interfere with seed germination of some crops. In case of wheat it has been observed that in effluent irrigated plots the seeds germinate one week later than the plain water irrigated plots. This condition was observed seven years after the start up of effluent irrigation. The crop, however, developed normally and yield levels were about the same as for plain water irrigated crop. Pulse crops have been found to be more sensitive to effluent at germination stage. Difficulty in germination in saline soils has been reported for many crops(6). In such crops modification in sowing or planting practices has been recommended to counter the effect of soil salinity during early stages of crop development.

Remarkable ability of soils to recover original physico-chemical balance has been demonstrated in some experiments where effluent irrigation was totally stopped after 8th year while continuing the cropping pattern established at the beginning of the research project. Various physico-chemical characteristics have tended to revert to original levels after two croppings under plain water irrigation. Aberration in germination behaviour has also been observed to be removed in these soils.

Of the perrennial tree crops under effluent irrigation data for two species are now available. In Table 5 selected data recorded for large scale Eucalyptus hybrid plantation under flood irrigation for 8 years are given. Effluent irrigation has induced higher wood volume production. This has resulted in about 50 per cent higher pulpable wood yield in effluent irrigated plantations. It can be pointed out that the irrigation was started when trees were already 7 years old. Later research has shown that if effluent irrigation is begun from second year onward then total wood production can increase 100 per cent. First coppice crop currently under observation, is also showing more vigorous growth than unirrigated coppies crop. Faster growth has resulted in longer fibres and less dense wood. Pulp and paper qualities have shown improvement in general in effluent irrigated trees. Except tear factor all the other strength properties have given better values over unirrigated trees.

Other tree species, Sesbania gradiflora (Shewari or Augusti), has similarly given higher yields. In effluent irrigated conditions four year old crop has yielded 30 MT wood per acre as compared to 20 MT wood per acre from unirrigated and 27 MT wood per acre from plain water irrigated plantations. It is significant to note that even in irrigated conditions the effluents ones have given higher yields over plain water irrigated ones.

Research on irrigational utilisation of pulp and paper mill effluents has also encompassed several important medicinal and aromatic herbs and shrubs Table 2). In these cases, in addition to normal yield data, evaluation is being done in respect to changes in the contents and chemistry of active ingredients like alkaloids and essential oils. Tissue analysis of effluent irrigated crops has also been taken up for selected crops to determine salt accumulation in various parts of the plant receiving effluent. In a recently concluded study it has been found that in plain water irrigated sugar-cane the can juice contains 30 ppm. sodium, while in effluent receiving sugar-cane the cane juice contains upto 145 ppm. sodium. This accumulation may determine the nutritive value of effluent irrigated crops. Plant tissues react in a definite way to salt concentrations. Better pulp and paper characteristics observed for effluent irrigated crops. Plant tissues react in a definite way to salt concentrations. Better pulp and paper characteristics observed for effluent irrigated Eucalyptus wood can be explained on this basis. Plant tissue and ingredient reactions, therefore, require micro-level studies to pin-point the nature of changes that may have been taking place in the specific environment created by sustained effluent irrigation.

The studies carried out at Orient Paper Mills have made it possible to draw a cropping pattern and an irrigation system which can help in reducing the pollution load on rivers and other good water resources by way of diverting a major part of the effluents for irrigational use, and in the meantime, increasing crop yields per unit area. In our studies yield comparisons have been made between effluent irrigation and plain water irrigation. It may, however, be stressed that plain water irrigation is hardly available to 30 per cent of agricultural land in India.. In the Amlai project area the percentage of irrigated agricultural land is less than 2 per cent. In such localities the effluent irrigation of crops in a scientifically designed way can greatly boost agricultural production. Likewise, effluent irrigated plantation forests in the vicinity of pulp and paper mills can contri bute greater quantities of better quality pulp wood, thereby reducing the pressure on already depleted forest wood resources.

ACKNOWLEDGEMENTS

The authors are deeply indebted to Shri I.M.Bhandari, Executive Vice President, Orient Paper Mills, Amlai (M.P.) for his constant support to the research project and for his permission to present this paper. Authors gratefully acknowledge the invaluable collaboration of scientists of National Environmental Engineering Research Institute, Nagpur between the years 1974-1978.

REFERENCES

1. Pande,M.C., Joshi,R.C., Khare, Alok and Singh, Man Mohan, 'Effect of Kraft Pulp Mill Effluents on Crop Performance and Soil Chemical Properties - Part I', IPPTA. 23-2(1986). 21-30.
2. Dubey, R.K., and Pande, M.C."Effect of Pulp and Paper Mill Waste-waters on soil chemical properties". IPPTA. 17-3(1980), 24-29.
3. Pande, M.C., Joshi, R.C., Khare, Alok and Singh, Man Mohan. "Studies in the Disposal of Pulp and paper Mill Effluents in Eucalyptus Plantations". Paper under publication.
4. Dubey, R.K.Khare, A. "Standardisation of Pulp Mill Effluents for Irrigation Purposes". IPPTA. 17-2(1980). 20-22.
5. NEERI, Nagpur. "Utilisation of Pulp and paper Mill Waste-water for Agriculture". Report sponsored by Orient Paper Mills,Amlai (1979).
6. Diagnosis and Improvement of Saline and Alkali Soils, Agricultural Handbook No.60(1973) by U.S.D.A.

TABLE – 1

AVERAGE CHARACTERISTICS OF MILL WASTEWATERS AND PLAIN WATER USED IN IRRIGATION STUDIES.

Parameters	Untreated Grade-III Effluent.	Treated Effluent Grade-III Anaerobically	Plain Water
pH	8.8	8.2	8.0
EC mmhos/cm at 25°C	2.2	2.0	0.28
Calcium meg/L	5.2	4.9	1.51
Magnesium meg/L	0.8	0.3	0.7
Sodium meg/L	20.0	18.3	1.73
Potassium meg/L	0.7	0.4	0.051
Chloride meg/L	9.0	8.2	1.26
Carbonate meg/L	0.1	–	0.2
Bicarbonate meg/L	14.0	12.8	1.96
Sulphate meg/L	1.8	1.6	0.45
BOD Mg/L	250	100	nil
COD Mg/L	1080	590	nil
Total dissolved solids Mg/L	1800	1550	250
Suspended solids Mg/L	380	170	30

TABLE - 2
LIST OF PLANTS AND VARIETIES GROWN UNDER EFFLUENT IRRIGATION

(A) Rabi Crops		
1. Wheat	- Varieties	1. Kalyan sona 2. U.P. 301 3. Hybrid - 65 4. HDM - 1593 5. Moti 6. HDM - 1553 7. Narmada - 4 8. RR - 21 9. Heera 10. Local strain
2. Barley	- Varieties	1. K - 12 2. Local strain
3. Oats	- Variety	1. Local strain
4. Gram	- Varieties	1. Gulabi Chana 2. T-87 3. Local strain
5. Safflower	- Variety	1. Standard cultivated
6. Japan rape	- Variety	1. Light green leaves.
(B) Kharif Crops		
1. Paddy	- Varieties	I. Padma 2. IET 1991 3. Anupama 4. Kaveri 5. Ratna 6. Basmati(Tilak)
2. Maize	- Varieties	1. Ganga - 2 2. Ganga - 5 3. Double Deccan 4. Chandan - 3
3. Jowar	- Varieties	1. NJ - 156 2. PSH - 2 3. CSH - 1
4. Bajra	- Variety	1. SB - 1
5. Ground nut	- Variety	1. SB - XI
6. Moong	- Varieties	1. Pusa baisakhi 2. S - 8 3. Kopargaon 4. Chamki
7. Urid	- Varieties	1. Krishna 2. No. 55 3. S - 1

8. Arhar	- Varieties	1. UP PAS - 120 2. Local strain
9. Soyabean	- Variety	1. Gaurav
10. Sugar-cane	- Variety	1. CO - 1307 2. CO - 1148

(C) <u>Miscellaneous crops</u>

1. Kenaf	- Variety	1. G - 12 2. HC - 583
2. Roselle	- Variety	1. Kalasin green.
3. Banana	- Variety	1. Basrai (Kabuli dwarf)
4. Napier grass	- Variety	1. Standard cultivated
5.Urena	- Variety	1. Congo hybrid strain
6. Sun-hemp	- Variety	1. Standard cultivated
7. Lucerne	- Variety	1. Improved hybrid
8. Cotton	- Varieties	1. AK 235 2. H 4
9. Barseem	- Variety	1. Tetraploid.

(D) <u>Tree crops</u>

1. Eucalyptus	- Variety	1. Hybrid
2. Coconut	- Variety	1. Hybrid T X D.
3. Sesbania grandiflora	Variety	1. Standard cultivated
4. Su-babool	- Varieties	1. K - 132 2. K - 28 3. Silvi - 4 4. El - Salvador
5. Poplar	- Variety	1. Clonal hybrid G - 3.

(E) <u>Medicinal and aromatic plants</u>

1. <u>Costus speciosus</u> (Keu kanda)
2. <u>Rauwolfia serpentina</u> (Sarpagandha)
3. <u>Centella Asiatica</u> (Brahma-manduki)
4. <u>Catharanthus roseus</u> (Soda-bahar)
5. <u>Abrus precatorius</u> (Gunchi)
6. <u>Hyoseymus niger</u> (Khurasani - ajvayan)
7. <u>Hyoscymus muticus</u> (do)
8. <u>Ocimum basilicum</u> (French basil)
9. Mentha arvensis (Peppermint)
10. Hibiscus ablemoschus (musk-dana)
11. Plantago ovata (isapgul)
12. Solanum khasianum (Badi Katili)
13. Spilanthes acmella (akarkora)
14. <u>Ammi majus</u>
15. <u>Metricaria</u> sp.

TABLE - 3

SOIL CHARACTERISTICS BEFORE AND AFTER EFFLUENT IRRIGATION (AVERAGED VALUES)

Soil Type	pH 1:25	Organic matter %	Exchangeable cations (meg/100 gm)				E.C. M. Mhos/Cm at 250°C	Analysis of saturation extract (meg/L)						
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	CO_3^{-}	HCO_3^{-}
Virgin sandy clay soils (Type A)	6.2	0.59	3.6	1.6	0.32	0.57	0.58	3.7	0.3	0.8	0.7	1.7	-	2.3
Virgin clay loam soils (Type B)	4.5	1.13	4.2	2.1	0.7	0.5	2.1	4.0	1.6	0.9	0.8	2.1	-	4.0
Type A irrigated with effluent	7.9	1.20	7.4	0.75	1.64	0.66	2.1	24.0	0.16	2.48	0.25	35.2	-	9.6
Type B Irrigated with effluent	8.3	1.50	12.6	1.32	2.1	0.71	3.4	23.1	1.3	3.46	0.18	38.6	-	12.0

TABLE - 4

YIELD PATTERN OF SELECTED CROPS UNDER EFFLUENT IRRIGATION(AVERAGED VALUES)

Crop	Grain yield(Quintals per acre)				Residual matter yield(Quintals per acre)			
	Plain water irri-gated	Effluent irrigated			Plain Water irri-gated	Effluent irrigated		
		1975-76	1980-81	1985-86		1975-76	1980-81	1985-86
1. Wheat	24.0	26.5	24.5	22.6	28.7	32.6	28.3	25.5
2. Barley	16.5	18.9	18.3	18.0	26.9	30.6	30.4	28.5
3. Paddy	26.8	30.7	28.5	26.6	30.8	34.5	32.5	31.2
4. Maize	20.0	20.5	18.6	18.0	90.0	100.0	95.8	95.9
5. Kenaf	2.6	4.5	3.8	3.9	14.0	20.0	18.0	15.0
6. Moong	4.5	5.0	4.0	3.0	6.3	6.4	6.0	5.0
7. Sugarcane	45.0	46.0	48.0	46.0	22.8	22.7	23.0	22.0
8. Barseem*	2.0	1.5	1.3	1.2	20.0	21.31	20.0	18.5
9. Safflower	3.5	-	3.2	4.0	8.6	-	7.8	11.0

* In case of braseem the residual matter yield means total green fodder yield available from 5 cuttings taken during 4 months.

TABLE - 5

RESPONSE OF EUCALYPTUS HYBRID TO EFFLUENT IRRIGATION

Parameters	Effluent irrigatdd	Unirrigated
1. Mean tree height(Meters)	17	14
2. Mean annual increment(m^3) per acre	5.440	3.620
3. Bark contents(w/w)	9.20	7.65
4. Wood density	0.497	0.607
5. Wood fibre length(mm)	1.14	1.04
6. Wood fibre diameter(micron)	10.80	10.70
7. Bulk density(kg/m^3)	230	234
8. Hollocellulose(%)	74.55	72.78
9. Lignin (%)	26.35	25.00
10. Reject free unbleached pulp yield (%)	45.50	47.30
11. Tensile index(n.m/g)	75.72	61.76
12. Burst index($Kpa.m^2/g$)	5.82	4.37
13. Tear index($m.N.m^2/g$)	5.81	7.61
14. Double fold	788	310
15. Brightness(%P.V.)	28.0	24.0