WATER POLLUTION CONTROL AT MYSORE PAPER MILLS LIMITED

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ABSTRACT

Mill location and production processes have been outlined in the paper. In-plant recycling measures have been highlighted. The nature and quantum of effluents generated from various production units have also been defined. A combined efficient treatment of effluents in two stages namely primary clarification and secondary biological oxidation by activated sludge process is discussed in detail with respect to plant and process details. The problems faced in the early stages and modifications made in the plant to overcome these problems have been discussed. Efficiency in both primary and secondary stages of treatment is shown. A comparison is drawn between the prescribed limits and actual discharge levels of pollutants. The paper also discusses in detail the unique nature of treatment facility that exists at Mysore paper Mills, where mixed treatment of effluents from Paper mill, Sugar mill and township sewage is being practised successfully to minimise the costs.

1. INTRODUCTION

The Mysore paper Mills situated on the banks of river Bhadra in Karnataka has combined capacity of 1,05,000 TPA for pulp and paper and in addition a 2500 TCD sugarmill integrated into the complex. It is the largest paper mill complex under on roof anywhere in India. The expansion in the field of Newsprint in 1982 and diversification to the sugarmill complex in 1984 has necessitated the use of a very huge quantity of water which is amply met from the river Bhadra which forms the natural border on the southern and eastern sides of the mill. The mill has an area of 620 acres including its township.

Although MPM has installed a water treatment plant capable of handling 1,23,000 m^3/d of water the actual intake of water is limited

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to about 90,000 m^3/d by efficient reuse of waste water in various intermediate process stages.

The mill generates about 80,000 m^3/d of waste water which is effectively treated by the activated sludge process alongwith domestic dewage from MPM township, before discharging it to river Bhadra.

The mill is contributing its mite to the protection of environment by efficient treatment of effluent to meet the stringent limits prescribed for the effluent discharge by the Karnataka State Pollution Control Board (KSPCB). The pollution levels in the river Bhadra monitored by KSPCB confirms this fact (Annexure I). The Mysore Paper Mills is one of the few mills which gets a full rebate of water cess, in Karnataka.

2. MANUFACTURING PROCESSES

The mill has three pulping lines, two producing bleached kraft pulp (BKP) and the third producing high yield Cold Soda refined mechanical pulp (CSRMP). The old pulp mill producing BKP has a capacity of 90 tpd of chemical pulp. The second line of BKP (120 tpd) and CSRMP (200 tpd) were added during the expansions of 1978-82.

In the chemical pulp mills the chipped bamboo, eucalyptus and hard woods are cooked in stationary digesters by kraft process. This is followed by a four stage counter current washing, cleaning, thickening and bleaching in a C/E/H/H sequence.

The CSRMP stream involves soaking of screened, washed and presteemed eucalyptus chips with Cold dilute caustic soda. The soaked chips are pressed to extract excess liquor, refined in two stages with an intermediate stage of brown stock washing, cleaned in three stages, thickened and bleached with calcium hypochlorite in two stages.

The spent liquors from all the three pulp mills are concentrated by evaporation and burnt in a recovery furnace of 270 tpd solids capacity to recover the spent chemicals as well as the heat value.

The calcium hypochlorite required for bleaching is produced on site in the hypoplant which has a capacity to produce 1300 m^3/d of bleach liquor at 30 gpl. available chlorine. The paper machines No. 1,2 and 3 in the cultural mill have been brought upto a combined capacity of 30,000 TPA of writing, printing and packaging papers. All the thjree are of single wire fourdrinier type machines of vintage 1937, 1954 and 1964. The Modern newsprint machine, PM-4 with a capacity of 75,000 TPA newsprint, has a twin wire former with a speed of 700 m/min. and was commissioned in 1982.

The Sugar mill was commissioned in 1984 and has a capacity of crushing 2500 tpd of sugar cane and is provided with thyrister controlled D.C. drives in the mill house. It is totally integrated with the paper mill complex and derives its power requirement and low pressure steam requirement from the power block of the mill.

3. IN-PLANT TREATMENT MEASURES:

In the newsprint mill the consultants Jaakko-Poyry of Finland have done the basic process engineering and have incorporated the latest process technology. By closing the inplant water usage cycles the fresh water requirement has been kept at as low as 190 m^3/ton of paper, probably the lowest in the country.

The fresh water requirement is minimised in other paper machines and pulp mills also by proper in-plant measures.

The recycling of waste water in various units is explained below:

3.1. Back water discharged from PM-4 wet end is taken to polydisc filter and thickeners to recover fibre which is recycled back to the system. The combined filtrate from the above system is used in:

a) Stock dilution in paper machine
b) Slushing of purchased pulp
c) Vat and tower dilutions and filter sprays in pulp mills
d) In pulp cleaning dilutiuons.

3.2. The filtrates of save all systems of PM 1,2 and 3 are used similarly and recovered fibres are recycled.

3.3. B5 washer filtrates in chemical pulp mills and pressafiner filtrate from CSRMP are precessed in closed chemical recovery system.

3.4. Bleach washer filtrates in chemical pulp mills at the stages E H H are recycled for vat dilution in counter current & only chlorine washer filtrate is drained. CSRMP bleach washer filtrate is used for vat dilution.

3.5. The decker and thickener filtrates of pulping units are recycled for inlet dilution of cleaning systems.

3.6 Condensates from paper machines, TG house and sugarmill are recycled back to the boilers. The black liquor recovery evaporator surface condenser water is utilized as spray in washing and bleaching units in the pulping section. Any surplus is used as make-up cooling water through cooling tower of TG house.

Final condensates from recovery evaporators is used in lime mud tank dilutions in recovery section.

Evaporator condensates from sugar mill is used for crusher spray and cooling water make up. The cooling water systems are completely closed.

4. NATURE & QUANTUM OF EFFLUENT DISCHARGED FROM VARIOUS UNITS:

Because of the diverse nature of different manufacturing and accessory units, the effluents from them vary widely in characteristics. The paper machine effluents in general are slightly acidic with a pH of 4.5 to 5, hardly have any colour and contain a comparitively greater amount of suspended matter. The effluent from pulping units are alkaline, highly coloured and have a greater amount of dissolved solids. The pollutants in the effluent from recovery section are mainly due to spillage or leakage which is minimised by proper supervision.

The sugar mill effluents contain usually a low level of solids, mainly dissolved, with no colour but high BOD and COD whereas the effluent from the paper mills is around 76,800 m^3/d, that from sugar mill is only about 3000 m^3/d. Because of the variation in the nature of this effluent during cleaning of the mill, the effluent is collected in an equalising tank from which it is mixed into the main effluent stream.

The characteristics of the effluents and the rates of discharge from different process units are given in Annexure-II.

5. EXTERNAL TREATMENT OF EFFLUENT

5.1. Piping: Originally it was proposed to segregate the high BOD effluents from pulp mills and recovery areas and the low BOD paper mill effluents. With view of diverting the paper mill effluent after primary clarification for irrigation purposes avoiding an expensive secondary biological treatment. But due to the difference in levels of various drains between the old mill and the new mill this view was modified. The two separate streams of effluent from various process areas have been connected to the treatment plant by 2.7 KM RCC pipe lines as shown in annexure III. The flow and characteristics of the two steams and the sewage are shown in Annexure IV. The piping has been designed to take advantage of gravity flow there by avoiding trouble-some and costly effluent pumping station. In addition 1.2 KM of inplant piping and 2.0 KM of yard piping has been done for effluent treatment plant.

5.2. Plant Design and operation: The effluent treatment Plant equipment was supplied by M/S Hindustan Door-Oliver Ltd., in the year of 1981 and has a capacity of handling 84,000 m^3/d of effluent with a BOD load of 22,430 Kg./d and 55 load of 30,000 Kg./d (Annexure V).

It is based on the activated sludge process which comprises of a primary clarification, forced aeration with activated sludge, nutrients like urea and diammonium phosphate and supplemented by town sewage, followed by a secondary clarification, as shown in Annexure VI.

5.3.1. **Primary Treatment:** The two streams of effluents entering the ETP are subjected to coarse screening on a covered bar screen of 12 mm openings for the removal of gross solids and floating lebris. The bar screen is provided with motor driven rake mechanism to remove trapped particles. These coarse particles if allowed to enter the primary clarifier, would interfere with raking system as well as underflow pumping. The screened effluent is then measured with a parshall flume type flow meter fitted with integrater and recorder.

The effluent is then taken into two separate primary clarifiers of dimensions 45.7 m dia x 3.66 m SWD and 36.6 m dia x 3.66 m SWD where + 80 % of suspended solids are removed by sedimentation in a retention time of about 3 hrs. The surface loading of the clarifiers is of the order of 1.3 $m^3/m^2/hr$.

5.3.2. **Secondary treatment:** The biological treatment is based on the same stabilizing processes that take place during natural purification in a river or lake. This self purification is the result of the action of micro organisms. They utilize organic materials as the source of energy and as raw material for the synthesis of new cell material. However, self purification in nature is rather slow. But this natural purification rate is substantially increased by optimising the conditions. The basic process involved is oxidation and is explained as follows:

a) Oxidation of pollutants and cell synthesis

Organic material	Bacteria	
+ O_2	Cells	New Cells + CO_2 + H_2O
+ NH_3		

b) Cell decomposition:

$$Cell + O_2 = CO_2 + H_2O + NH_3$$

The activated sludge method is adopted where the site is too small for other methods or when the effluents have high BOD. In the activated sludge process the sludge, rich in bacteria is not stationary but is kept suspended in waste water during the process.

The clarifier has a high torque, centrrally driven rake mechanism, inlet baffle well and a sludge, collection chamber.

The clarified effluents from both the clarifiers are subjected a mixed secondary biological treat-ment.

The clarified effluents are mixed with, nutrients such as Diammonium phospnate and urea, and (township) sewage to correct the effluent for the nutrient and bacteriological deficiencies. The Nutrients are prepared in four FRP lined M S circular tanks and dosing is done at the flash mixer. The daily requirement of DAP and urea is about 150 Kg each.

The domestic sewage is mixed at the flash mixer with a view to save on cost of nutrient chemicals.

The clarified effluent enriched with nutrients and bacteria enters the RCC aeration tank of 18,300 m^3 capacity (Dimensions 127 m x 36 m x 4 m) which is kept well aerated with 14 nos. of 50 HP surface aerators with an oxygenating capacity of 2.2-2.4 kg. per KWH. The mixed liquor suspended solids (ML SS) concentration is maintained at 4500-5000 mg/l. and organic loading is of the order of 0.2 Kg. BOD/Kg MLSS/day. The aeration basin is designed for +90 % removal of incoming BOD. The effluent is given a retention time of 10 hrs. in the aerators. The quality of activated sludge is closely monitored with respect to sludge solume index (SVI), sludge volume density (SVD) and the ratio of MLVSS to MLSS.

The mixed liquor after aeration tank is taken into two nos. of secondary clarifiers of dimensions 42.6 m dia x 3.66 m SWD each where it is allowed to settle for 3 hrs. The secondary clarifiers have a traction driven rake mechanism and a bottom feed. In order to maintain the desired level of MLSS in aeration tank, the required quantity of secondary sludge is recirculated and the excess is taken to sludge thickener.

5.3.3. **Sludge handling:** There is an elaborate sludge handling system for disposing off the primary and excess secondary sludges. The underflow from primary clarifiers is pumped at 1 % consistency into a gravity thickener of 19.8 m dia x 3.66 m SWD, equipped with high torque centrally driven rake mechanism.

The thickener overflow at 4 % consistency is further dewatered to 20 % consistency on a vacuum belt filter of 3.67m dia x 3.67 m face. The solid loading is about 35 $Kg/m^2/hr$ and the filtering area of the drum is 42 m^2.

The underflow sludge collection sumps of both the primary and secondary clarifiers as well as that of thickener have been provided with high pressure water lines for periodical flushing of the pits to prevent clogging of sludge pipes. At present the recovered fibre from the vaccum filter is being disposed off as land fill. But on a trial basis it has been recycled for making wrapper paper alongwith virgin pulp. But the high ash content has posed a problem in this repect and an extensive cleaning may be necessary before actual utilization. Proposals are also on way to utilize the same for i) board making by some other enterprenuers; ii) to make pelletised fuel alongwith other waste materials after further dewatering.

The final treated effluent from the secondary clarifier is discharged through an 1.3 KM open channel to Bhadra river. The discharge characteristics conform strictly to the limits prescribed by the KSPCB. The discharge characteristics alongwith the limits prescribed by KSPCB and those in IS-2490 are tabulated in Annexure VII.

6. CRITARIA FOR EFFICIENT OPERATION:

The input load of flow SS and BOD to ETP fluctuates considerably with time because of the diverse nature of polluting units and also because all of them may not be running at any given time. Also there will be shock loads due to leakage or overflow in process units even though every percaution is taken to minimise them.

The treatment of effluents with such varying characteristics requires a close and continuous monitoring of inlet effluent quality and adjustmenting the operating conditions in the plant suitably.

If the inflow to clarifiers is highly alkaline, the flocculation and sedimentation is affected drastically resulting in carry-over of fines in overflow. This problem was faced during the commissioning of the plant. The operation was improved by intermixing of paper machine and pulp mill effluents before taking into primary clarifiers. A minimum addition of alum is maintained to the inflow occasionally when acidic paper machine effluents are not available.

The alkaline sediment when taken to thickeners causes a heavy foam at the surface carrying fibres alongwith the foam. Eventually this floating mass gets thicker and enters the overflow. This is avoided by providing spray line of clear effluent at the surface if the pH is not controlled properly at the initial stages itself, the resultant sludge will have very poor filtration quality on the vacuum filter due to the clogging of wire cloth, reducing the output of the filter.

A higher amount of suspended solids in the inlet effluent causes over loading of clarifiers. Such shock loads are being tackled by keeping a constant vigil on the sludge accumulation in the primary clarifier and keeping it at a minimum.

In the secondary treatment of effluent pH, temperature, MLSS level, and extent of aeration play an important role. All these have to be maintained at optimum levels depending upon the load to achieve a good treatment. The variations in pH and temperature come down to stable values by the time the effluent reaches the secondary stage. Also atmospheric temperature fluctuations at Bhadravati are within a small range, daily variation being within a range of 8-10°C. The MLSS level is kept at an optimum by adjusting bleeding of secondary sludge to suit to suit the Aerator inlet BOD.

Finally in the secondary clarifiers the settling and removal of sludge should be fast. Otherwise anaerobic decay of organic matter starts resulting in foul odour. Also the suspended matter begins to float on the surface of clarifier.

7. IMPROVEMENTS AND MODIFICATIONS IN THE PROCESS

7.1. Sludge handling:

Originally the filter was designed to operate with a 200 mesh wire cloth with lime mud being used as a filtering aid. However, the addition of lime mud has been avoided by changing over to coarser wire mesh to suit the filtering rate without the filtering aid. This has reduced the sludge handling problem because amount of sludge produced has come down. However, this has not effected the filtrate quality adversely.

7.2. Combined secondary treatment:

Since the trade effluent and sewage are being treated together in the secondary stage by activated sludge process, we have achieved good savings in the quantity of nutrient addition by more than 85 %. The sewage also helps to develop healthy bacteria in the aeration system in a faster rate because it introduces fresh bacteria into the system, which brings about a quick reduction in BOD.

Our experience and observations by operating at various MLSS levels has shown us the optimum level of MLSS to be around 4500-5000 mg/l which is considerably higher than the usually recommended value of 3000 mg/l.

By employing this high level of MLSS in the aerators we have achieved

a) Faster reduction of colour, BOD and COD.
b) Foam free aerator operation without any sprinklers ensuring good oxygenation;
c) Good settling in secondary clarifiers.

7.3. Addition of sugarmill effluent and colour removal:

It has been observed that after the MPM sugar mill was commissioned in 1984, the sugar mill effluent joining the ETP in the primary stage during the sugarmill season, has a good effect on colour reduction in the final effluent.

The reasons for this are not clearly known and the field is open for further study. Probably the traces of SO_2 and the slightly lower pH in the sugar mill effluent cause partial precipitation of lignin matter on the fibres.

8. OPERATING EFFICIENCY:

In spite of the varying nature of effluent and fluctuating load, MPM can produly claim for a plus point for treating the effluents very efficiently.

An efficient reduction in colour, SS, BOD and COD is achieved by careful manipulation of the various parameters and inputs in the plant operation.

An overall reduction of suspended solids by +80 %, BOD_5 by +90 % and COD by +80 % is achieved.

A stagewise reduction in the important effluent characteristics are given in Annexture No. VIII.

It may be mentioned that MPM effluent treatment is one of the most sophisticated and efficient in the industry.

9. COST OF EFFLUENT TREATMENT:

A combined treatment of trade effluents and sewage has enabled MPM to reduce costs considerably. The cost of treating such a large volume of effluent. It is about Rs. 76.1/tonne of paper produced or Rs. 1.06/Kg. of BOD reduction during the treatment process. These recurring of expenditures amount to about Rs. 85 lakh per annum.

A break down is these costs is given in Annexure No. IX and X.

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ANNEXURE - I*

WATER QUALITY IN RIVER BHADRA DURING OCTOBER, 1985

S.No.	Parameters Monitored	Upstream of MPM & VISL Bhadravati	Down stream of Bhadravati Town**
1.	Temp. °C	30	30
2.	pH	7.7	7.4
3.	Turbidity units	15	30
4.	Dissolved oxygen mg/l	7.0	3.5
5.	BOD_5 mg/l	1.0	3.0
6.	COD mg/l	36	48
7.	Total Kjeldahl Nitrogen mg/l	1.0	1.3
8.	Nitrogen, NO_3+NO_2, mg/l	0.02	0.06
9.	Conductivity	15	25
10.	Hardness mg/l	96	110
11.	Calcium mg/l	20	23
12.	Magnesium mg/l	9	13
13.	Chloride mg/l	30	38
14.	Sulphate mg/l	15	19
15.	Sodium mg/l	11	19
16.	Alkalinity Total	96	112
17.	Phenolphthaei alkalinity	nil	nil
18.	Flouride mg/l	0.2	0.2
19.	Iron mg/l	0.3	0.5
20.	Fascal coliform MPN/100 ml	240	2400
21.	Total Coliform MPN/100 ml	350	2400
22.	Zinc mg/l solids mg/l	nil	nil
23.	Total dissolved solids mg/l	100	180
24.	Fixed dissolved solids	94	170

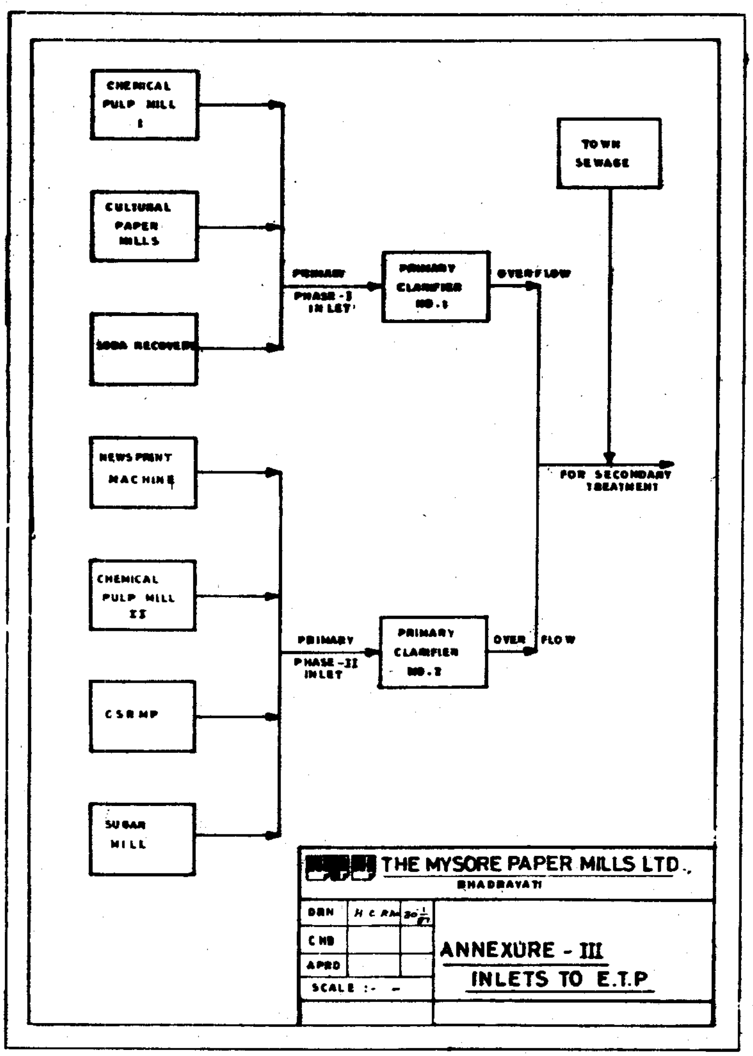
* Extract from Ref.1.

**Before this point partially treated industrial effluent and untreated effluents sewage from Bhadravati Town join river Bhadra in addition to treated MPM effluent.

ANNEXURE – II

FLOW RATE AND CHARACTERISTICS OF SECTIONAL EFFLUENTS

S.No.	Section	Flow 1000m³/d	pH	SS mg/l	BOD_5 mg/l	COD mg/l	Colour Pt-Co Units
1.	Chemical Pulp Mill	35-40	8-9	250-300	150-250	450-800	600-1000
2.	CSRMP	6-8	7.5-8.5	350-450	250-350	800-1000	1000-1500
3.	Soda Recovery	8-10	7.5-9.0	100-150	80-150	250-500	500-1000
4.	Cultural Mills	9-12	4.5-5.0	400-800	50-150	200-550	50-100
5.	Newsprint	7-10	4.5-5.0	400-600	40-60	150-250	100-150
6.	Sugar mill	2.5-3.5	3.5-5.0	100-200	300-600	500-1000	50-100



ANNEXURE -IV

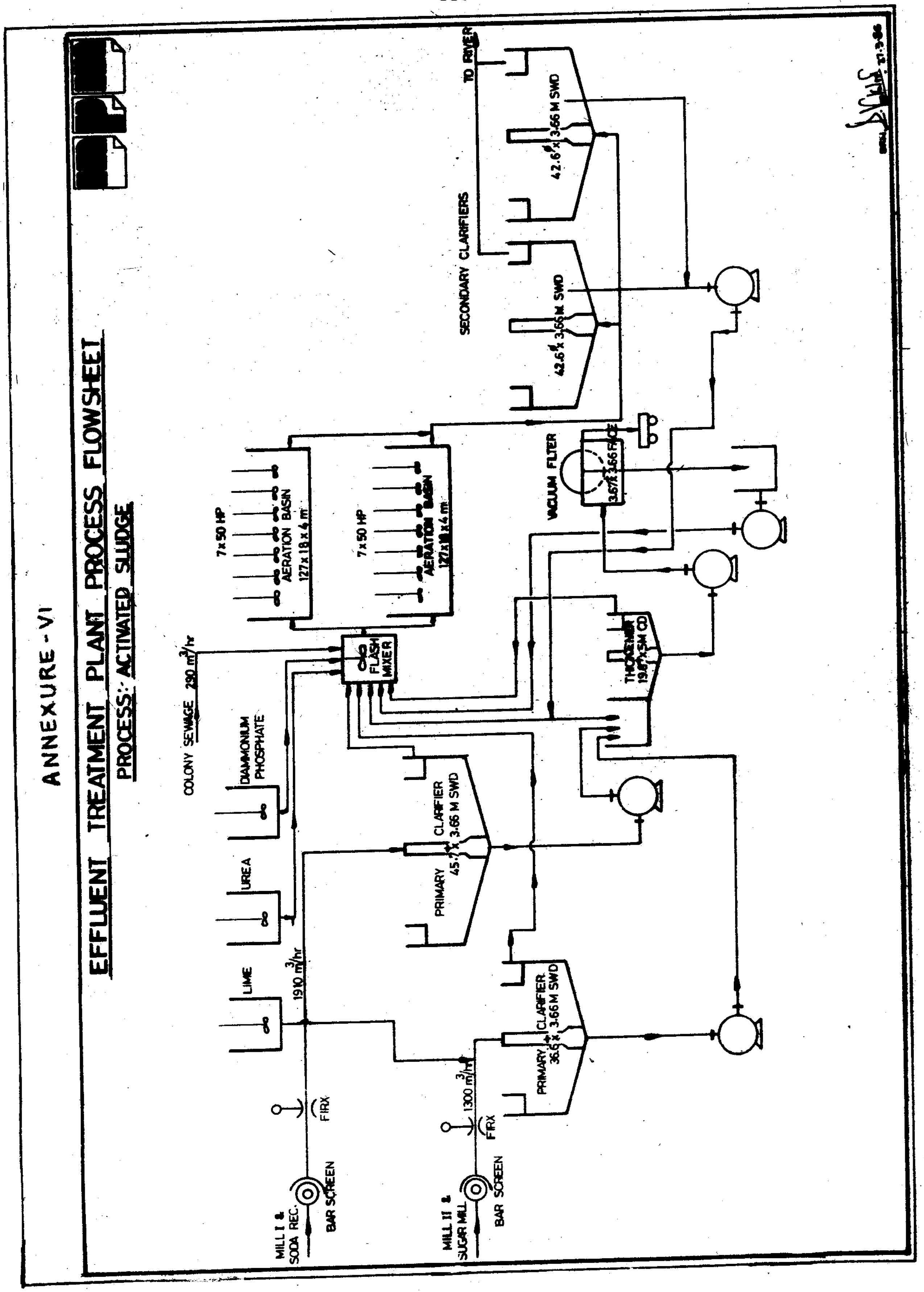
E T P INLET CHARACTERISTICS AND FLOW

S.No.	Stream	Flow x1000m³/d	pH	SS	BOD_5 mg/l	COD mg/l	Colour Pt-Co Units
1.	Primary Phase-I inlet.	45-50	6.0-9.0	250-300	100-150	300-400	600-800
2.	Primary Phase-II Inlet.	25-30	6.0-9.0	350-450	200-250	600-800	600-800
3.	Town Sewage	4-4.5	7-8	80-100	100-150	400-600	100-150

ANNEXURE V

AN OVERVIEW OF M.,P.M. EFFLUENT TREATMENT PLANT

Capital cost	Rs. 2.5 corres.
Operating cost	Rs. 6 lakh/month
Process	Activated sludge
Hydraulic capacity	84,000 m^3/d
Primary clarifiers.	Two nos. Dia 45.7m & 36.6 m.
BOD loading capacity after primary treatment	16.680 Kg/day
SS removal	+80 %
Aeration basin	127 m x 36m x 4 m
Surface serators	14 Nos. of 50 HP each
BOD removal	+ 90 %
Secondary clarifiers	2 Nos. 42.6 m dia each
Vacuum belt filter	One No. 3.67m dia x 3.67 m face.
Power	Connected load 928 KW Power consumption 15,590 KWH/day
Nutrient requirement	DAP 150 Kg/day Urea 150 Kg/day.


ANNEXURE - VI
EFFLUENT TREATMENT PLANT PROCESS FLOWSHEET
PROCESS: ACTIVATED SLUDGE
MILL I & SODA REC.
BAR SCREEN
FIRX
MILL II & SUGAR MILL
BAR SCREEN
FIRX
1300 m3/hr
1910 m3/hr
LIME
UREA
DIAMMONIUM PHOSPHATE
COLONY SEWAGE 290 m3/hr
PRIMARY CLARIFIER 36.6 x 3.66 M SWD
PRIMARY CLARIFIER 45.7 x 3.66 M SWD
FLASH MIXER
7 x 50 HP
AERATION BASIN 127 x 18 x 4 m
7 x 50 HP
AERATION BASIN 127 x 18 x 4 m
THICKENER
VACUUM FILTER
SECONDARY CLARIFIERS
42.6 x 3.66 M SWD
42.6 x 3.66 M SWD
TO RIVER

ANNEXURE – VII

M.P.M. DISCHARGE CHARACTRERISTICS COMPARED TO K5PCB AND ISI SPECIFICATIONS

S.No.	Parameter	Units	Limits as per IS:2490 1981	Limits prescribed by K5 PCB	MPM Discharge Characteristis
1.	Colour & Odour	–	See note	See note	Colour pale yellow odour NIL
2.	Suspended solids (Max)	mg/l	100	100	60-100
3.	Particle size of SS	–	Shall pass 850 u IS sieve.	Shall pass 850u IS sieve	Pass 850 u IS sieve
4.	Dissolved solid (in org.)	mg/l	2100	2100	400-800
5.	pH value	–	5.5-9.0	6.0-8.5	6.8-7.6
6.	Temp. max.	°C	40	40	20-32
7.	Oils & Grease max.	mg/l	10.0	10.0	6-8
8.	Total residual chlorine max.	mg/l	1.0	1.0	nil
9.	Ammoniacal nitrogen aS N Max.	mg/l	50.0	50.0	0.5-1.0
10.	BOD_5 max .	mg/l	30	30	15-30
11.	COD max.	mg/l	250*	250	100-200
12.	Sulphate as SO_4 max.	mg/l	1000	1000	50-150
13.	Sulphide as S max.	mg/l	2.0	2.0	0.5-0.8
14.	Phenolic compounds as C_6H_5OH max.	mg/l	1.0	1.0	nil

Note: All efforts should be made to remove colour and unpleasant odouras practicable.

For paper..............etc., industries this value may be relaxed.

ANNEXURE - VIII

STAGE WISE REDUCTION IN IMPARTANT EFFLUENT CHARACTERISTICS AND TREATMENT EFFICIENCY

S.No.	Parameter	ETP inlet	Primary outlet	Final outlet	Efficiency %		
					Primary treat-ment	Second-ary tr-eatment	Over all
1.	pH	8.5	8.5	7.2	-	-	-
2.	Colour Pt-Co units	700	700	350	-	50	50
3.	Suspended solids mg/l	400	100	80	75	20	80
4.	BOD_5 mg/l	260	180	25	27	86	90
5.	COD mg/l	800	500	150	37.5	70	81

ANNEXURE - IX

COST OF EFFLUENT TREATMENT IN M.P.M.

		Rs.
1.	Power : 15,000 units/day x 30 days 4,50,000 units/month @ Rs. 1.00	4,50,000.00
2.	Urea : 150 kg/day 4.50 tonnes at Rs. 3000.00	13,500.00
3.	DAP : 150 Kg/day 4.5 tonnes at Rs. 3800.00	17,100.00
4.	Sludge transport at Rs. 14.40/tonne for 3000 tons/month	43,200.00
5.	Maintenance & Spares (Approx.)	50,000.00
6.	Salary & Wages (Approx)	35,000.00
	Total	6,08,800.00
	paper production/month Finished)	= 8000 Tonnes

Effluent Treatment cost per tonne of paper = Rs. 76.10.

ANNEXURE - X

COST PER KG OF BOD REDUCTION

1.	Inlet BOD	260 mg/l
2.	Effluent flow per day	80,000 m^3
3.	Oxygen demand $\frac{260x1000x80,000}{1000}$	28,800 Kg/d
4.	Outlet BOD at 25 mg/l	2000 Kg/d

BOD treated = 20,800 - 2000 = 18,800 Kg/d

or 5,74,000 Kg/month

Cost of BOD reduction 6,08,800/5,74,000 Kg

= Rs. 1.06/Kg of BOD