A
PROJECT REPORT
ON

Wastewater Management and Performance Evaluation of the ETP in a Pulp and Paper Mill: A Case Study

SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF

MASTER OF ENGINEERING
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CERTIFICATE

It is certified that the work presented in this thesis entitled **"Wastewater Management & Performance Evaluation of ETP in a Pulp and Paper Mill: A Case Study"** by Vaibhav Nautiyal, University Roll No. 9103 in partial fulfillment of the requirement for the award of the degree of Master of Engineering in Environmental Engineering, Delhi Technological University (Formerly Delhi College of Engineering), Delhi, is an authentic record. The work is being carried out by him under our guidance and supervision in the academic year 2010-2011. This is to our knowledge has reached requisite standards.

The work embodied in this minor project has not been submitted for the award of any other degree to the best of our knowledge.

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ABSTRACT

Pulp and paper industry is responsible for large discharge of highly polluted effluents, which often be treated by biological treatment process. Pulp and paper industry accounts for a considerable share of the industrial enterprises, production, employment and exports in the Indian economy and, one of the energy intensive industries in Indian manufacturing.

The pulp and paper industry is comprised of three primary types of producers (1) pulp mills, which manufacture pulp from wood and other materials (such as wastepaper); (2) paper mills, which manufacture paper from wood pulp and other fiber pulp; and (3) paperboard mills, which manufacture paperboard products from wood pulp and other fiber pulp.

Many types of wastewater treatment systems are employed in pulp and paper industry. However, no single process will reduce all the major pollutants to regulatory standards and hence a combination of methods need to be used which include physical, physico-chemical, and biological systems. While most wastewater streams in the mill are controlled individually or pretreated before joining the common sewer, in most cases the combined wastewater receives the final treatment with exception of uncontaminated cooling water. The quality of the effluent desired and the mode of final disposal determine the type of the treatment to be adopted.

The high water consumption in Indian pulp and paper industry is mainly due to obsolete process technology, poor water management practices and inadequate wastewater treatment. This thesis discusses about the treatment method being employed by Naini Group of Industries that has two pulp and paper mills under its umbrella i.e. Naini Tissues Limited and Naini Papers Limited. In addition to the study of the whole manufacturing process of paper making, water and wastewater management of Naini Tissues Limited was studied and performance evaluation of the ETPs at both the plants was carried out.

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CHAPTER 1

INTRODUCTION

1.1 TOPIC OVERVIEW

The world of pulp and paper industry continues to expand production and increasingly, plants are being built in newly industrialized countries. The dominant process is ***the kraft or sulphate process***. Historically, substantial pollution problems have been associated with pulp manufacturing operations. Following the recognition of large scale environmental contamination by ***organochlorines*** due to their formation in bleach plants, the industry implemented a number of process internal changes and continued to develop process external treatment processes. The bleach plant of kraft mills generates a substantial proportion of the total process effluents.

The introduction of extended delignification and oxygen delignification can substantially reduce the quantities of lignin entering the bleach plant. Residues from oxygen delignification can be cycled to the recovery process. Overall, this reduces the demand for bleaching agents and hence reduces the generation of organochlorines. Together with substitution of elemental chlorine (Cl_2) with chlorine dioxide, these systems have substantially reduced levels of AOX being discharged from bleach kraft mills. Organochlorines, however, have not been eliminated from discharges, merely reduced. Swedish research has shown detectable levels of toxicologically chlorinated dioxins and dibenzofurans in the effluents from mills that use chlorine dioxide; so-called elemental chlorine free (ECF) mills.

This stems from the fact that ECF processes are not free of elemental chlorine. Commercial chlorine dioxide generators in many cases co-generate molecular chlorine. Moreover, chemical reactions and pH dependent chemical equilibria in pulp bleaching reactions involving chlorine dioxide liberate molecular chlorine. This molecular chlorine then reacts with chemicals released from the wood.

Organochlorine production in ECF processes is within a broad range of 0.1-10.0 kg per tonne of air dried pulp produced. The global average is unknown. The elimination of organochlorine discharges can be achieved by the use of TCF (Totally Chlorine Free) bleaching where agents such as hydrogen peroxide and ozone are used. A necessary prerequisite of TCF bleaching is a pulp with low residual lignin (kappa number) produced through extended cooking and oxygen delignification. Conversion of existing mills favours this technology over chlorine dioxide based processes in economic terms. In addition the cost of new TCF plant is cheaper than ECF.

In terms of effluent toxicity, TCF systems produce a less toxic effluent than elemental chlorine bleached processes when realistic conditions using actual mill effluents are employed in the experiments as opposed to samples synthesized in the laboratory. Recently, however, effects have been identified in fish populations exposed to effluents from pulp mills producing both bleached and unbleached pulp. The chemicals responsible are not removed by advanced secondary treatment and are suspected to be plant sterols or their derivatives which have a strong endocrine disruptive action.

The identification of environmental effects due to both bleached and unbleached pulping activities has led to the concept of the totally effluent free mill. A key impediment to fully closing mill circuits is the difficulty of closure of the bleach lines. Although problems exist with closing both ECF and TCF lines, those involved in closing ECF lines appear to be the most difficult and costly to resolve.

The presence of high levels of chlorides in an acid bleach medium has been associated with severe corrosion problems, and hence the possibility of explosion in recovery boiler systems. Moreover, the presence of organochlorines in both filtrates of ECF bleach liquors and in sludges from treatment plants means that they cannot be incinerated without the emission of products of incomplete combustion including the dioxins and furans (PCDDs and PCDFs).

Accordingly, in order to reach likely regulatory standards in the future, closure of mill circuits will be necessary. This is likely to be more easily achievable with TCF technology since there will be a lower requirement for chloride removal from the process liquors. In addition there is much greater potential to deal with these streams without the use of incineration technology. In order to avoid transferring environmental impacts from one medium to another, incineration of ECF derived sludges and other solids will need to be eliminated. Hence, movement of the industry generally into TCF processes rather than ECF systems promises more rapid achievement of the zero discharge goal.

In order to promote sound environmental practice and move towards zero effluent mills, environmental regulators need to promote the need for process changes. Extended cooking and oxygen delignification of pulps is required to reduce the quantities of lignin entering the bleach plant. The bleach plant should be based upon totally chlorine free technologies to reduce effluent toxicity as much as possible and to facilitate water and process chemical recycling without need for incineration of sludge contaminated with organochlorine compounds. Under these conditions, the mill circuits can effectively be closed and operated totally effluent free (TEF).

1.2 INDIAN PULP AND PAPER INDUSTRY: AN INTRODUCTION

The pulp and paper industry is one of India's oldest and core industrial sector. The socio-economic importance of paper has its own value to the country's development as it is directly related to the industrial and economic growth of the country. Although paper has many uses, its most important contribution to modern civilization is its use as a medium to record knowledge. Paper manufacturing is a highly capital, energy and water intensive industry. It is also a highly polluting process and requires substantial investments in pollution control equipment. In India, around 905.8 million m^3 of water is consumed and around 695.7 million m^3 of wastewater is discharged annually by this sector.

India's current average fresh specific water consumption of about 150 m^3/tonne of product is far above the global best specific water consumption of 28.66 m^3/tonne (for large scale wood based pulp and paper mill) and this large gap is primarily attributed to the use of obsolete technology / equipments and poor water management practices.

The large water requirements and consumption by the Indian pulp and paper industries has led to, water fast becoming a scarce commodity and lowering of the groundwater table and thus increased pumping costs and more importantly water shortage in many regions. Realizing the importance of water and excessive usages of water by pulp and paper sector, Central Pollution Control Board (CPCB) has taken initiative to develop the water conservation guidelines and water consumption standards.

The Indian Paper Industry accounts for about 1.6% of the world's production of paper and paperboard. Currently Indian paper industry is consuming only about 7 million MT or about 3% of the total wood consumed in India; about 90% is consumed as fuel wood.

Additional raw material requirement by 2012-13 is anticipated to be about 8 million tons of wood which will be about 6% of total consumption of the country. This would require afforesting 2 million Ha of land mass to maintain proper ecological balance.

India produces 9.37 million tonnes of paper per year (2008 – 2009) through 525 paper manufacturing mills at a capacity utilization of approximately 60 percent. The number of paper manufacturing mills has increased consistently from just 17 in 1951 to around 600 in Year 2002 with an annual installed capacity of 6.2 million to meet the increasing demand. However since 2001 – 02, the number of mills have fallen sharply to 309 in the year 2004 primarily due to increased environmental regulatory pressure, water shortage etc and during the year 2008-2009, the figure has now reached to 449 mills to make a variety of papers of various descriptions including newsprint and rayon-grade pulp. Out of these, 80 belong to large paper mill category defined as those having chemical recovery system and generally producing over 24,000 tonnes per annum, with a total installed capacity to make 3.45 million tonnes per annum.

Table 1.1: Segregation of Indian Mills (Basis: Raw material Use)

Raw material	Number of Mills	Scale of Operation	% Contribution to installed capacity
Wood	32	100-700	38
Agro Residues	110	30-100	32
Recycled Fiber	383	5-400	30

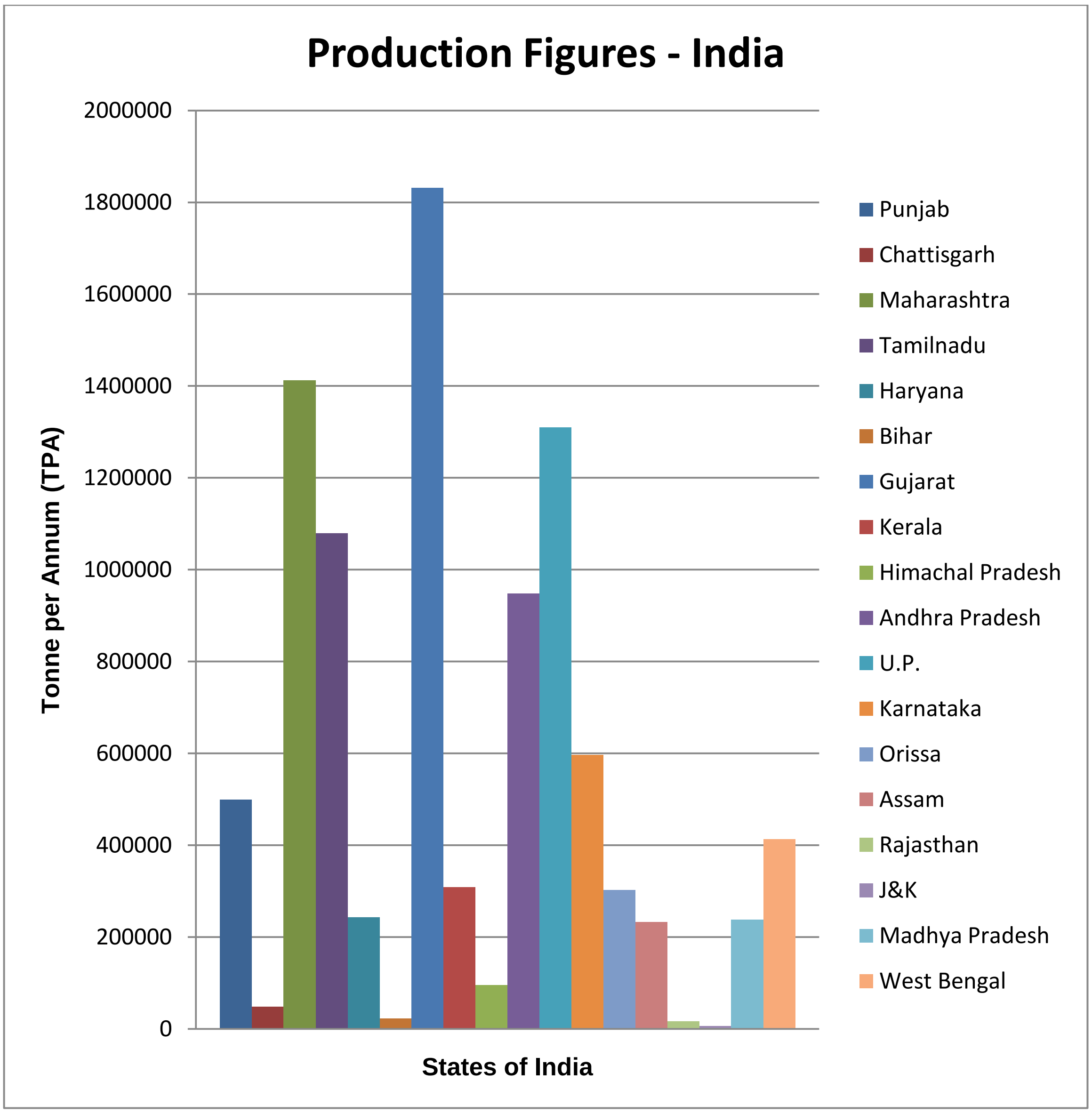


Figure 1.1: Production Figures of different states of India

1.3 OBJECTIVES OF THE STUDY

The objectives of this study are:

1. To study the manufacturing process of paper making at Naini Tissues Ltd., Kashipur.
2. To study the water consumption and the generation of wastewater from different sections of the mill.
3. To analyze the mill drains to ETP and chemical characterization of the same.
4. Chemical Characterization of the different Inlet and Outlet points of ETP to evaluate the performance of the ETP under study.

CHAPTER 2

LITERATURE REVIEW

Wood is chemically very highly complex. The basic structural element of the cell walls is cellulose. Lignin and hemicelluloses are also distributed throughout the cell walls, although this distribution is poorly understood *(Minor 1982; Fengel and Wegener 1989).*

An integral and economically vital part of alkaline pulping mill operations is the regeneration of the cooking liquors *(Fengel & Wegener 1989; Minor 1982).*

Gullichsen (1991) notes that half of the wood is dissolved during the manufacture of chemical pulp, and this, when combusted in the recovery boiler, provides heat for the plant systems.

Aqueous organic solvents such as methanol and ethanol are used for de-lignification to produce a bleachable pulp which can be bleached with non-chlorine chemicals. Pilot scale tests have given high pulp yields with strength properties similar to sulphite and kraft pulps *(Sierra-Alvarez & Tjeerdsma 1995).*

The principal aim of pulp bleaching is to increase the brightness of the pulp. The chromophoric (light absorbing) components in pulps are predominantly functional groups of degraded and altered residual lignin which is both darker and more tightly bound to the fibres than the original lignin component *(McDonough 1992).*

The early bleaching of paper manufactured from non-wood fibres was carried out using sunlight *(Farr et al. 1992).*

Chlorine gas became a common bleaching agent in the first thirty years of the twentieth century *(Reeve 1996).*

In conventional bleaching processes around 90kg of chlorine was used per tonne of pulp produced. This figure is stated to have now been reduced to around 25 Kg per tonne and often to around 3-10 kg/tonne (RSAES 1989) although *Kringstadt & Lindstrom (1984)* state the chlorine charge to the pulp slurry to be between 60 and 70 kg per tonne of produced pulp.

Suntio et al. (1988) published a compilation of over 250 chemicals present in pulp mill effluents. 180 of those listed are chlorinated compounds comprising phenolic, together with neutral and acidic compounds. The chlorophenolic compounds, particularly chlorophenols, catechols, guaiacols and syringols are important components and have, for example, been isolated from samples taken in every sub-basin of the Baltic Sea *(Sodergren 1993)*. A proportion of these compounds appear to be derived from the degradation of high molecular weight chlorinated material formed during chlorine bleaching *(Martin et al. 1995)*. It is only recently that reference compounds for some of these exotic chemicals have been synthesised for analytical purposes *(Smith et al. 1994 a & b; Hyotylainen 1994)*.

Buser et al. (1989) identified a series of methyl-, polymethyl- and alkyl-polychlorodibenzofurans in pulp mill sludge and sediment which had previously been misidentified as polychloroxanthones and polychloro-xanthenes. *van Loon et al. (1990)* have described the analysis of chlorolignins in pulp mill effluent, although these were not quantified. A significant component of the high molecular mass compounds was identified as chlorolignosulphonic acids by *van Loon (1992)* in effluents discharged to the River Rhine. Chlorinated diones and enol lactones with mutagenic properties have been identified *(McKague et al. 1988)* while subsequent studies *(McKague et al. 1989)* have revealed the presence of trichlorothiophenes, compounds with significant potential for bioaccumulation. *McKague et al. (1990)* also identified chloroacetones at a number of mills. Low chlorinated PAHs present in pulp effluents were isolated by *Koistinen et al. (1992)*.

Development of an indigenous system with a prime objective to minimize the AOX generation at source i.e. before bleaching, which is very difficult to achieve in conventional batch cooking system followed by oxygen delignification without affecting the quality of pulp to meet CREP (Corporate Responsibility for Environmental Protection) requirement. Looking into ecology and economic conditions, the Indian Paper Mills require improved/modified cooking system i.e. Modified conventional batch cooking (MCBC) followed by Oxygen Delignification in case they are unable to afford modern cooking system for minimizing the AOX generation because of their high capital cost *(Rathi B. H. et al, 2007)*.

Manoj Kumar U. Borekar et al, 2007 described an efficient way of processing sludge including waste-to-energy aspects and attention has been focused on the performance of the energy recovery.

Abeer M. Adel and Nehal S. El-Mougy, 2007 examined the strength and brightness properties of hand sheets made from bacterial treated pulp i.e. kraft bagasse pulp was treated with several bacterial strains, including Pseudomonas flurescens (Pf1 and Pf2); and Bacillus subtilis (B) for 10, 20, 30 and 40 days.

C. H. Tyagi and Dharm Dutt, 2007 studied the suitability of *S. spontaneum* for pulp and paper making. The proximate chemical analysis indicates that it is a bulky material having comparatively lower extractives and lignin content with higher homo-cellulosic content. It requires lower cooking chemicals and shorter cooking cycle in order to produce chemical grade pulp. The unbleached pulp showed a good response towards O_2 delignification and reduces Kappa Number by 62 per cent.

Vyavahare Manoj, 2007 studied the effect of using a bio-culture which comprised of the use of blend of bacterial colonies in place of conventional Urea and DAP dozing and found it to be a cost effective solution.

Singh Rashmi, Bhardwaj Nishi K., 2010 highlighted the progress of application of enzymes in refining including various types of enzymes, mechanism of action and their effects. They also found that enzymes are valuable in order to develop better filtration or net formation for better quality of paper, saving electrical energy, reduced steam consumption in drying operation and improved drainability of pulp but with a limitation of reducing the pulp viscosity.

Sood Y. V. et al, 2010 studied the significance of high brightness in paper from Agro Residues Pulp and its impact on Environment. In agro residue pulp higher brightness more than 80% has shown adverse effect on fibre strength which got dropped by 31%, tearing strength dropped by 27% and print through increased by 43%. Stronger paper with better print quality can be made if brightness is restricted to 80% ISO brightness, however alongwith it CIE whiteness W C/2 of 100% and dirt count below 20 mm^2/m^2 are also to be included as quality parameters.

Kulkarni A. G., 2010 highlighted the problems associated with build-up of non-process elements in chemical recovery cycle and the status of established technologies and also carried out laboratory scale studies on removal of non-process elements, employing the cooling and evaporative crystallizations. Majority of the mills in India, which are using wood as their main raw material are faced with the problem of severe build-up of the Non-

Process Elements, such as potassium and chloride in the pulping and chemical recovery cycle. Chloride and Potassium enter the liquor cycle through wood, process water and chemicals.

Dixit A. K. et al, 2010 highlighted the basics of Desilication Technology developed by CPPRI and successfully demonstrated the desilication of both bamboo and rice straw black liquor in wider range of silica content (2-15 gpl).

Combination of biological and physic-chemical treatment method is adopted for colour removal of paper mill effluents. On treatment with Trichoderma sp in batch studies, 72% colour reduction was achieved within 24 hours. In continuous mode, treating effluent with the same fungus with a fluidized bed reactor, around 27% colour reduction was achieved. This biologically treated effluent is further treated with a poly-electrolyte (potash alum) to improve the colour reduction. Maximum colour reduction of 81% was obtained by this combined treatment. *(V. Saravanan and T. R. Sreekrishnan, Deptt. Of Biochemical Engg. And Biotechnology, IIT Delhi, 2005)*

Das A. and Raju N. Naga, 2011. The upgradation of Effluent Treatment Plant with new technology of Moving Bed Bio-film Reactor with diffused aeration system shows great potential in reducing the pollution load of final treated effluent discharge by 50% over surface aeration system.

CHAPTER 3

METHODOLOGY

The Plant was visited and a thorough in-depth study was carried out to study the various sections in the Mill on Daily Basis. Different Sections of the Mill were visited for several days to get an in-depth knowledge of how the paper is being manufactured and what are the systems involved/employed within the mill. The plant officials within the mill from different sections explained the working of every section including the technical terms associated wherever required. Observations were made regarding the wastewater generation sources from the mill and the questions were raised for the same to Mr. Deepak Jindal (Manager-EHS) and other technical staffs, which were satisfactorily answered and explained whenever required.

Wastewater generation sources were marked out with the quantity of wastewater production from the same was also recorded. A Water/Mass Balance chart for the whole mill was hence prepared with the help of Mr. Deepak Jindal. Similarly, the wastewater drains coming from different sections were marked out for further analysis to check different parameters in the wastewater. The common drains from the mill to ETP were also analyzed for the same purpose.

For carrying out performance evaluation of ETP, a comprehensive program was taken up to analyze various parameters like pH, BOD, COD and TSS at different inlet/outlet points of an ETP. A performance evaluation was carried out for both the plants of Naini Group of Industries i.e. Naini Tissues Ltd. And Naini Papers Ltd. so as to have an understanding of how the reduction potential changes if Oxygen De-lignification is being employed to reduce the chlorine consumption (Naini Papers Ltd. has an Oxygen Delignification Plant while Naini Tissues Ltd. has not installed the same yet) and to enhance the cost optimization of the whole paper making process.

Sampling and Analysis: Monitoring of pollutants involves sampling and chemical analysis of the parameters. The sample should be taken at the inlet and outlet of each treatment units in addition to the final effluent as it leaves the mill premises. It will be prudent to monitor the river/nallah in sensitive regions and around drinking water sources to study the impact on water quality due to effluent discharge.

The data obtained from sample analysis are meaningful provided the samples are representative which necessitate a well designed sampling technique. There is no universal procedure for sampling which exists, hence sampling must be tailored to fit the operation of each manufacturing unit, regulatory requirements and economics.

In general, samples should be taken from a point one third the water depth from the bottom in case of deep drains. When collecting samples, care should be taken to avoid creating excessive turbulence.

Basically, the samples may be collected either on grab or composite basis. It is suggested to collect composite samples everyday for the final effluent whereas grab samples may be taken at other points. However, weekly composite samples for each treatment units and combined wastewater are recommended. The composite samples of individual drains may be carried out once in three months.

Frequency of sampling and parameters to be analysed for different wastewater sources are given in Table. Suspended solids, pH, BOD, COD and colour constitute as primary pollutants needing frequent analysis. Sodium absorption ratio (SAR) may be considered once in a month in the combined wastewater. Estimation of parameters should be done according to the various standard procedures available.

Collection of Effluent Samples

To have a true & representative samples, twenty four (24) hours composite sampling of the identified effluent streams were carried out in two batches. The sampling was generally continued for forty eight (48) hours to absorb variations due to change over of product manufactured , process / system shut down if any .The sampling was carried out in following streams:

- Individual streams
- Combined influent to ETP
- Inlet & Outlet of various stages of ETP

Analysis of Effluent Samples

The composite effluent samples thus collected from selected mills were analysed for major pollutional parameters such as pH, TSS, COD, BOD, chlorides, colour etc. All the analysis was carried out as per standard testing procedures of Standard Method for Examination of Water & Waste Water (APHA-AWWA-WPCF).

Measurement of Effluent Flow

The measurement of effluent flow is a critical & sensitive parameter with respect to assessment of magnitude of various pollutants discharged in effluent. The mill was having flow measurement devices in the effluent drains like V notch / rectangular notch, and hence flow measurement was carried out in accordance with standard procedures. The flow measurement was carried out after regular intervals during the entire duration of effluent sampling and efforts were made to have realistic figures.

Table 3.1: Sampling Schedule for Water Pollution Monitoring

Parameters	*Combined Wastewater*	*Treatment Units*	*Final Effluent*	*River Water*
pH	D	D	D	D
Suspended Solids	D	W	D	-
BOD (5 days at 20 deg. C)	B	B	D	W
DO	-	-	D	W
COD	T	T	A	M
Colour	M	W	D	W
MLSS/MLVSS	-	D	-	-
SVI	-	D	-	-
Alkalinity	W	W	-	-
SAR	M	-	-	-

D – Daily B – Bimonthly A – Alternate days

W – Weekly T – Twice a week M – Monthly

Table 3.2: Chemical parameters commonly determined in natural waters and water supplies

No.	*Chemical Species*	*Significance in Water*	*Methods of Analysis commonly used*
1.	Acidity	Indicative of industrial pollution, acid mine drainage	Titration
2.	Alkalinity	Water treatment, buffering, algal productivity	Titration
3.	Ammonia	Productivity, pollution	Colorimetry
4.	Calcium	Hardness, Productivity treatment	Atomic absorption
5.	Chloride	Saline water contamination	Titration, potentiometry
6.	Oxygen	Water quality	Titration, electrochemical
7.	BOD	Water quality, pollution	Microbiological titration
8.	COD	Water quality, pollution	Chemical oxidation-reduction
9.	pH	Water quality, pollution	Potentiometry

Importance of Quantitative Analysis

Quantitative analysis serves as the keystone of engineering practice. Environmental engineering is perhaps most demanding in this respect, for it requires the use of not only the conventional measuring devices employed by engineers but, in addition many of the techniques and methods of measurement used by chemists, physicists and some of those used by biologists.

Every problem in environmental engineering must be approached initially in a manner that will define the problem. This approach necessitates the use of analytical methods and procedures in the field and laboratory, which have proved to yield reliable results. Once the problem has been defined quantitatively, the engineer is usually in a position to design facilities that will provide a satisfactory solution.

After construction of the facilities has been completed and they have been placed in operation, usually constant supervision employing quantitative procedure is required to maintain economical and satisfactory performance.

The increase in population density and new developments in industrial technology are constantly intensifying old problems and creating new ones. In addition, engineers are forever seeking more economical methods of solving old problems. Research is continuously under way to find answers to the new problems and better answers to old ones. Quantitative analysis will continue to serve as the basis for such studies.

Character of Problems

Most problems in environmental engineering practice involve relationships between living organisms and their environment. Because of this, the analytical procedures needed to obtain quantitative information are in often a strange mixture of chemical and biochemical methods, and interpretation of the data is usually related to the effect on microorganisms or human beings. Also, many of the determination used fall into the realm of microanalysis because of the small amounts of contaminants present in the samples. Ordinarily, the amounts determined are a few milligrams per litre and often they are found only in few micrograms.

1. **Determination of pH of given samples using (1) universal indicator (2) pH paper, and (3) digital pH meter.**

Principle

pH value of water indicates the hydrogen ion concentration in water and concept of pH was put forward by Sorenson (1909). pH is expressed as the logarithm of the reciprocal of the hydrogen ion concentration in moles/litre at a given temperature. The pH scale extends from 0 (very acidic) to 14 (very alkaline) with 7 corresponding to exact neutrality at 25°C. pH is used in the calculation of carbonate, bicarbonate and CO_2, corrosion and stability index etc. While the alkalinity or acidity measures the total resistance to the pH change or buffering capacity, the pH gives the hydrogen ion activity. pH can be measured colorimetrically or electrometrically.

Colorimetric method is used only for rough estimation. It can be done either by using universal indicator or by using pH paper. The hydrogen electrode is the absolute standard for the measurement of pH. They range from portable battery operated units to highly precise instruments. But glass electrode is less subjected to interferences and is used in combination with a calomel reference electrode. This system is based on the fact that a change of 1 pH unit produces an electric charge of 59.1 mV at 25°C.

Apparatus

1. pH meter with electrode
2. Beaker
3. Thermometer
4. Colour comparator with discs
5. Cuvettes

Reagents

1. Buffer solutions
2. pH paper
3. Universal indicator

Procedure

(a) Using Universal Indicator

1. 10 mL of sample is taken in a cuvette.
2. Another 10 mL sample is taken in another cuvette and 0.2 mL of universal indicator is added and placed in the hole provided for.

3. A colour disc corresponding to this indicator is inserted into the comparator and the disc rotated such that the 2 circles indicate identical colours.
4. The reading is noted.
5. The procedure can be repeated using an indicator whose range is near the value obtained.
6. The exact pH is obtained.

(If comparators are not available, compare the colour with colours given in the chart.)

(b) Using pH Papers

1. Dip the pH paper in the sample.
2. Compare the colour with that of the colour given on the wrapper of the pH paper book.
3. Note down the pH of the sample along with its temperature.

(c) Using pH Meter

1. Dip the electrode in the buffer solution of known pH.
2. Switch on the power supply and take the reading. Standardize the instrument using the calibrating knob.
3. After cleaning, again dip the electrodes in the buffer solution of pH 7. Note the reading. If it is 7, the instrument is calibrated. If not, correct the value and is manipulated so that the reading in the dial comes to 7.0.
4. A solution whose pH is to be found is taken in a beaker and the temperature knob is adjusted such that the temperature of solution is same as that in dial.
5. The electrode is washed with distilled water and reused with the solution and then it is dipped in the solution.
6. The reading on the dial indicates the pH of the solution.

2. **Determination of the quantity of dissolved oxygen present in the given sample(s) by using modified Winkler's (Azide modification) method.**

Principle

Dissolved Oxygen (D.O.) levels in natural and wastewaters are dependent on the physical, chemical and biochemical activities prevailing in the water body. The analysis of D.O. is a key test in water pollution control activities and waste treatment process control.

Improved by various techniques and equipment and aided by instrumentation, the Winkler (or iodometric) test remains the most precise and reliable titrimetric procedure for D.O. analysis. The test is based on the addition of divalent manganese solution, followed by strong alkali to the water sample in a glass-stoppered bottle. D.O. present in the sample rapidly oxidises in equivalent amount of the dispersed divalent manganous hydroxide precipitate to hydroxides of higher valency states. In the presence of iodide ions and upon acidification, the oxidised manganese reverts to the divalent state, with the liberation of iodine equivalent to the original D.O. content in the sample. The iodine is then titrated with a standard solution of thiosulphate.

Apparatus

1. 300 mL capacity bottle with stopper
2. Burette
3. Pipettes, etc.

Reagents

1. Manganous sulphate solution ($MnSO_4.4H_2O$)
2. Alkali-iodide azide reagent
3. Conc. sulphuric acid
4. Starch indicator
5. Standard sodium thiosulphate solution (0.025N)
6. Standard potassium dichromate solution (0.025N)

Procedure

1. Add 2 mL of manganous sulphate solution and 2 mL of alkali-iodide azide reagent to the 300 mL sample taken in the bottle, well below the surface of the liquid.
2. Stopper with care to exclude air bubbles and mix by inverting the bottle at least 15 times.
3. When the precipitate settles, leaving a clear supernatant above the manganese hydroxide floc, shake again.

4. After 2 minutes of settling, carefully remove the stopper, immediately add 3 mL concentrated sulphuric acid by allowing the acid to run down the neck of the bottle.

5. Restopper and mix by gentle inversion until dissolution is complete.

6. Measure out 203 mL of the solution from the bottle to an Erlenmeyer flask. As 2 mL each of manganese sulphate and azide reagent have been added, the proportionate quantity of yellow solution corresponds to 200 mL of sample is =
$$\frac{200 \times 300}{(300-4)} = 203\,mL$$

7. Titrate with 0.025 N sodium thiosulphate solution to a pale straw colour.

8. Add 1–2 mL starch solution and continue the titration to the first disappearance of the blue colour and note down the volume of sodium thiosulphate solution added (V), which gives directly the D.O. in mg/L.

3. **Determination of B.O.D. exerted by the given sample(s).**

Principle

The Biochemical Oxygen Demand (B.O.D.) of sewage or of polluted water is the amount of oxygen required for the biological decomposition of dissolved organic matter to occur under aerobic condition and at the standardised time and temperature. Usually, the time is taken as 5 days and the temperature 20°C as per the global standard but where results are needed at the earliest, a 3-day BOD test at 27°C is being carried out.

The B.O.D. test is among the most important method in sanitary analysis to determine the polluting power, or strength of sewage, industrial wastes or polluted water. It serves as a measure of the amount of clean diluting water required for the successful disposal of sewage by dilution. The test has its widest application in measuring waste loading to treatment plants and in evaluating the efficiency of such treatment systems.

The test consists in taking the given sample in suitable concentrations in dilute water in B.O.D. bottles. Two bottles are taken for each concentration and three concentrations are used for each sample. One set of bottles is incubated in a B.O.D. incubator for 5 days at 20°C (3 days at 27°C); the dissolved oxygen (initial) content (D1) in the other set of bottles will be determined immediately. At the end of 5 days (or 3 days), the dissolved oxygen content (D2) in the incubated set of bottles is determined.

Then, mg/L B.O.D. = (D1 – D2)/P

where, P = decimal fraction of sample used.

D1 = dissolved oxygen of diluted sample (mg/L), immediately after preparation.

D2 = dissolved oxygen of diluted sample (mg/L), at the end of 5 days incubation.

Apparatus

1. B.O.D. bottles 300mL capacity
2. B.O.D. incubator
3. Burette
4. Pipette
5. Air compressor
6. Measuring cylinder etc.

Reagents

1. Distilled water
2. Phosphate buffer solution
3. Magnesium sulphate solution

4. Calcium chloride solution
5. Ferric chloride solution
6. Acid and alkali solution
7. Seeding
8. Sodium sulphite solution
9. Reagents required for the determination of D.O.

Procedure

1. Place the desired volume of distilled water in a 5 litre flask.
2. Add 1mL each of phosphate buffer, magnesium sulphate solution, calcium chloride solution and ferric chloride solution for every litre of distilled water.
3. Seed the sample with 1 mL of settled domestic sewage (Filtrate of Septic Tank at M/s Naini Tissues Ltd.).
4. Saturate the dilution water in the flask by aerating with a supply of clean compressed air for 45 minutes.
5. Highly alkaline or acidic samples should be neutralised to pH 7.
6. Destroy the chlorine residual in the sample by keeping the sample exposed to air for 1 to 2 hours or by adding a few mL of sodium sulphite solution.
7. Take the sample in the required concentrations. The following concentrations are suggested:

Strong industrial waste	: 0.1, 0.5 and 1 per cent
Raw and settled sewage	: 1.0, 2.5 and 5 per cent
Oxidised effluents	: 5, 12.5 and 25 per cent
Polluted river water	: 25, 50 and 100 per cent

8. Add the required quantity of sample (calculate for 650 mL dilution water the required quantity of sample for a particular concentration) into a 1000 mL measuring cylinder. Add the dilution water up to the 650mL mark.
9. Mix the contents in the measuring cylinder.
10. Add this solution into two B.O.D. bottles, one for incubation and the other for determination of initial dissolved oxygen in the mixture.
11. Prepare in the same manner for other concentrations and for all the other samples.
12. Lastly fill the dilution water alone into two B.O.D. bottles. Keep one for incubation and the other for determination of initial dissolved oxygen.

13. Place the set of bottles to be incubated in a B.O.D. incubator for 5 days at 20°C (or 3 days at 27°C). Care should be taken to maintain the water seal over the bottles throughout the period of incubation.
14. Determine the initial dissolved oxygen contents in the other set of bottles and note down the results.
15. Determine the dissolved oxygen content in the incubated bottles at the end of 5 days and note down the results.
16. Calculate the B.O.D. of the given sample.

4. **Determination of Chemical Oxygen Demand (C.O.D.) for given sample.**

Principle

Potassium dichromate is a powerful oxidising agent in acidic medium and is obtained in high state of purity. The reaction involved is:

$$\mathbf{C_nH_aO_b + cCr_2O_7^{2-} + 8cH^+ = nCO_2 + (a+8c)/2\ H_2O + 2cCr^{3+}}$$

where, $c = 2/3n + a/6 – b/3$

C.O.D. results are reported in terms of mg of oxygen. N/8 or 0.125 N solution of oxidising agent is used in the determination. Normality double the strength is used. This allows the use of larger samples. Thus, each ml of 0.25 N solution dichromate is equivalent to 2 mg of oxygen. An excess of oxidising agent is added, the excess is determined by another reducing agent such as ferrous ammonium sulphate. An indicator ferroin is used in titrating the excess dichromate against ferrous ammonium sulphate. Blanks are used also treated and titrated to get the correct value of C.O.D.

Apparatus

1. Reflux apparatus
2. Burettes
3. Pipettes

Reagents

1. Standard potassium dichromate solution 0.25N.
2. Sulphuric acid reagent.
3. Standard ferrous ammonium sulphate.
4. Ferroin indicator solution.
5. Mercuric sulphate.
6. Sulphuric acid crystals.

Procedure

1. Place 20.0 mL of sample (Dilutions to be made upto 20.0 mL depending upon the sample) in a refluxing flask.
2. Add 1g mercuric sulphate and a few glass beads..
3. Add 10.0 ml 0.25 N potassium dichromate solution and mix well.
4. Add the acid reagent (30 mL) through the open end of condenser and mix well.
5. Attach the flask to the condenser and start the cooling water.
6. Apply heat and reflux for 3 hours.

7. Cool and wash down the condenser with distilled water.
8. Dilute the mixture by adding about 80 ml of distilled water and cool to room temperature.
9. Titrate the excess dichromate with standard ferrous ammonium sulphate using ferroin indicator (2 to 3 drops).
10. The colour change from blue green to reddish indicates the end point.
11. Reflux in the same manner a blank consisting of distilled water of equal volume as that of the sample.

PREPARATION OF REAGENTS

1. **Manganous sulphate solution:** Dissolve 480 g $MnSO_4.4H_2O$, 400 g $MnSO_2.2H_2O$ or 364 g $MnSO_4.H_2O$ in distilled water, filter and dilute to 1 litre.
2. **Alkali-iodide-azide reagent:** Dissolve 500 g NaOH or 700 g KOH and 135 g NaI or 150 g KI in distilled water and dilute to 1 litre. Add 10 g sodium azide (NaN_3) dissolved in 40 mL distilled water. The reagent should not give colour with starch when diluted and acidified.
3. **Sulphuric acid concentrated:** 1mL is equivalent to about 3 mL alkali-iodide-azide reagent.
4. **Standard sodium thiosulphate 0.025 N:** Dissolve 6.205 g sodium thiosulphate ($Na_2S_2O_3.5H_2O$) in freshly boiled and cooled distilled water and dilute to 1 litre. Preserve by adding 5 mL chloroform or 0.4 g NaOH/L or 4 g borax and 5–10 mg HgI_2/L. Standardise this with 0.025 N potassium dichromate solution which is prepared by dissolving 1.226 g potassium dichromate in distilled water and diluted to 1 litre.
5. **Standard potassium dichromate solution 0.025 N:** A solution of potassium dichromate equivalent to 0.025 N sodium thiosulphate contains 1.226 g/L $K_2Cr_2O_7$. Dry $K_2Cr_2O_7$ at 103°C for 2 hrs before making the solution.
6. **Standardisation of 0.025 N sodium thiosulphate solution:** Dissolve approximately 2 g KI in an Erlenmeyer flask with 100 to 150 mL distilled water. Add 10 mL of H_2SO_4, followed by exactly 20 mL, 0.1 N potassium dichromate solution. Place in the dark for 5 minutes, dilute to approximately 400 mL and titrate with 0.025 N sodium thiosulphate solution, adding starch towards the end of titration. Exactly 20 ml 0.025 N thiosulphate will be consumed at the end of the titration. Otherwise, the thiosulphate solution should be suitably corrected.
7. **Starch Indicator:** Add cold water suspension of 5 g soluble starch to approximately 800 mL boiling water with stirring. Dilute to 1 litre, allow boiling

for a few minutes and let settle overnight. Use supernatant liquor. Preserve with 1.25 g salicylic acid/1 litre or by the addition of a few drops of toluene.

8. **Phosphate buffer solution:** Dissolve 8.5 g potassium dihydrogen phosphate (KH_2PO_4), 21.75 g dipotassium hydrogen phosphate (K_2HPO_4), 33.4 g disodium hydrogen phosphate heptahydrate ($Na_2HPO_4.7H_2O$) and 1.7 g NH_4Cl in about 500 ml distilled water and dilute to 1 litre. The pH of this buffer should be 7.2 without further adjustment. Discard the reagent if there is any sign of biological growth in the stock bottle.
9. **Magnesium sulphate solution:** Dissolve 22.5 g $MgSO_4.7H_2O$ in distilled water and dilute to 1 litre.
10. **Calcium chloride solution:** Dissolve 27.5 g anhydrous $CaCl_2$ in distilled water and dilute to 1 litre.
11. **Ferric chloride solution:** Dissolve 0.25 g $FeCl_3.6H_2O$ in distilled water and dilute to 1 litre.
12. **Sodium sulphate solution 0.025 N:** Dissolve 1.575 g anhydrous Na_2SO_3 in 1 litre distilled water. This is to be prepared daily.
13. **Seeding:** The standard seed material is settled domestic wastewater that has been stored at 20°C for 24 to 36 hours. A seed concentration of 1–2 mL/L is usually adopted.
14. **Standard potassium dichromate solution 0.25 N:** Dissolve 12.259 g $K_2Cr_2O_7$ primary standard grade previously dried at 103°C for 2 hours and dilute to 1 litre.
15. **Sulphuric acid reagent:** Concentrated H_2SO_4 containing 22 g silver sulphate per 4 kg bottle. Dissolve 22 g Ag_2SO_2 in 4 kg bottle and keep it for 2 days. This is the reagent.
16. **Standard ferrous ammonium sulphate 0.1 N:** Dissolve 39 g $Fe(NH_4)_2(SO_4)_2.6H_2O$ in distilled water. Add 20 mL conc. H_2SO_4 and cool and dilute to 1 litre. Standardise this against the standard dichromate solution. Dilute 10 mL standard $K_2Cr_2O_7$ solution to about 100 mL. Add 30 mL conc. H_2SO_4 and cool. Titrate with ferrous ammonium sulphate titrant using 2–3 drops of ferroin indicator.

Normality = (mL $K_2Cr_2O_7$ ×0.25)/(mL $Fe_4(NH_4)_2(SO_4)_2$)

CHAPTER 4

MANUFACTURING PROCESS IN A PULP AND PAPER MILL

4.1 INTRODUCTION TO MANUFACTURING PROCESS

Pulping is the means whereby the wood or agricultural residues like wheat straw or bagasse are reduced to a fibrous mass for onward processing into paper and board products. The two important processes used are sulphate or kraft process and sulphite process. All types of cellulosic materials can be processed by kraft digestion using caustic soda containing Na_2S and Na_2CO_3 in water. The digestion conditions vary with raw material used. Digestion time in batch process will range from 2 to 5 hours for wood materials and shorter time is employed if continuous digestion is adopted. The digester temperature is around 170-180^{o}C with a pressure around 10 atmosphere. Digestion conditions are changed including the chemical strength used depending on the raw material employed for pulping. After digestion is complete the contents are blown to tanks and the spent liquor (black liquor) is separated for chemical recovery. The pulp even after washing is brown in colour. The fibres from Kraft process are strong compared to those from sulphite process.

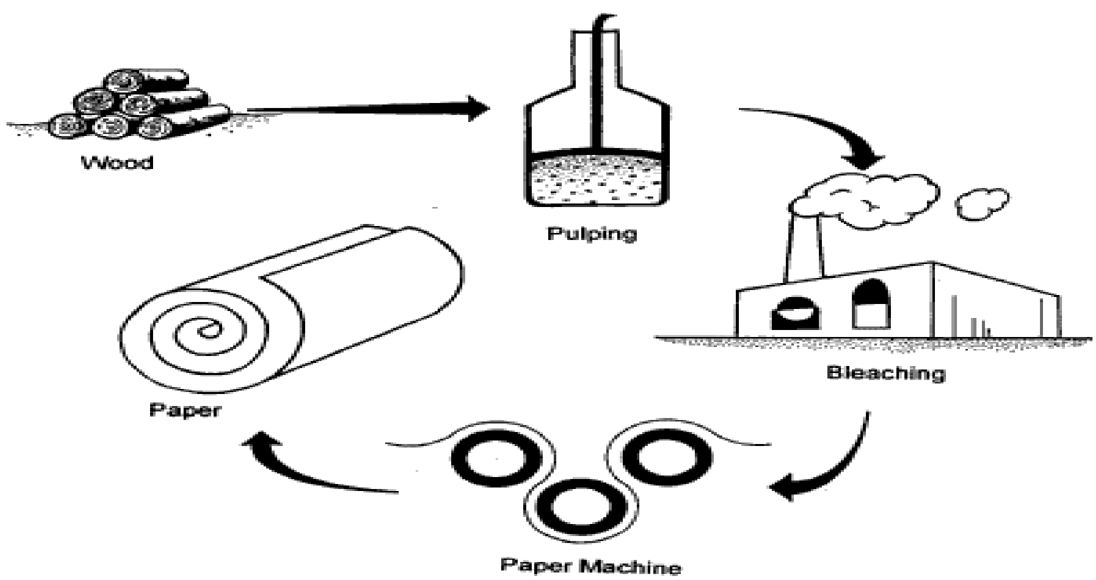


Figure 4.1: Diagrammatic representation of the production of pulp and paper using bleach process

The chemical pulps are generally bleached using a multistage process of three to six steps, depending upon the pulp characteristics. Hardwood pulps generally require less bleaching than softwood pulps content. Sulphite and bisulphite pulps are easier to bleach than kraft pulps, and can be manufactured entirely without bleaching with chlorine or its compounds although chlorine bleaching is used. The following text, therefore, largely considers the bleaching of kraft pulps which is the dominant production process on a global basis since they have a lower lignin.

Chlorine dioxide, despite handling difficulties, is largely replacing elemental chlorine in the initial bleaching stages. Its perceived advantages are: higher pulp brightness, improved fibre strength properties, lower chemical consumption and considerable reduction in the AOX of discharged effluents. Peroxide in combination with chlorine dioxide is often used in the later stages of bleaching chemical pulps.

The process of manufacturing paper from wood pulp is as per *Figure 4.2 (a) and Figure 4.2 (b)* giving an overview of the waste generation points classifying the wastes as Gaseous, Liquid and Solid from different sections of a typical Pulp and Paper Mill. The fundamental process in a typical pulp and paper mill process follows the steps as shown in Figure 4.2 (a) and (b). In preparation of paper ingredients such as fillers, dyes, starch and alum are added during the stock preparation stage so as to impart colour, strength and other mechanical properties to paper depending upon the requirement of the product. The final product are then cut into desired sizes and then sent to the Dispatch Section to be sent to the distributors.

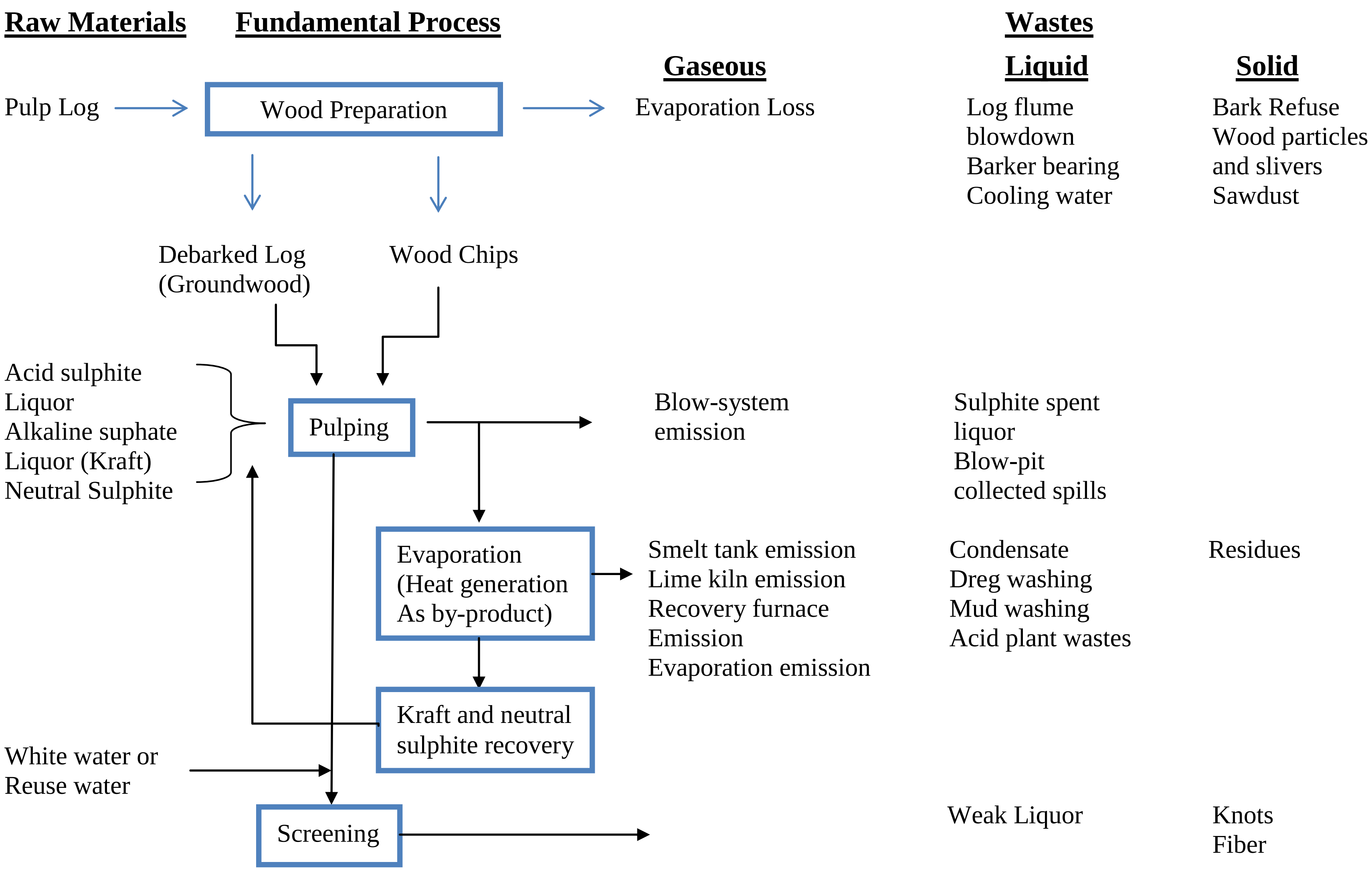


Fig 4.2 (a): Sources of wastes (gaseous, liquid and solid) from different processes in a typical Pulp and Paper (Part – I)

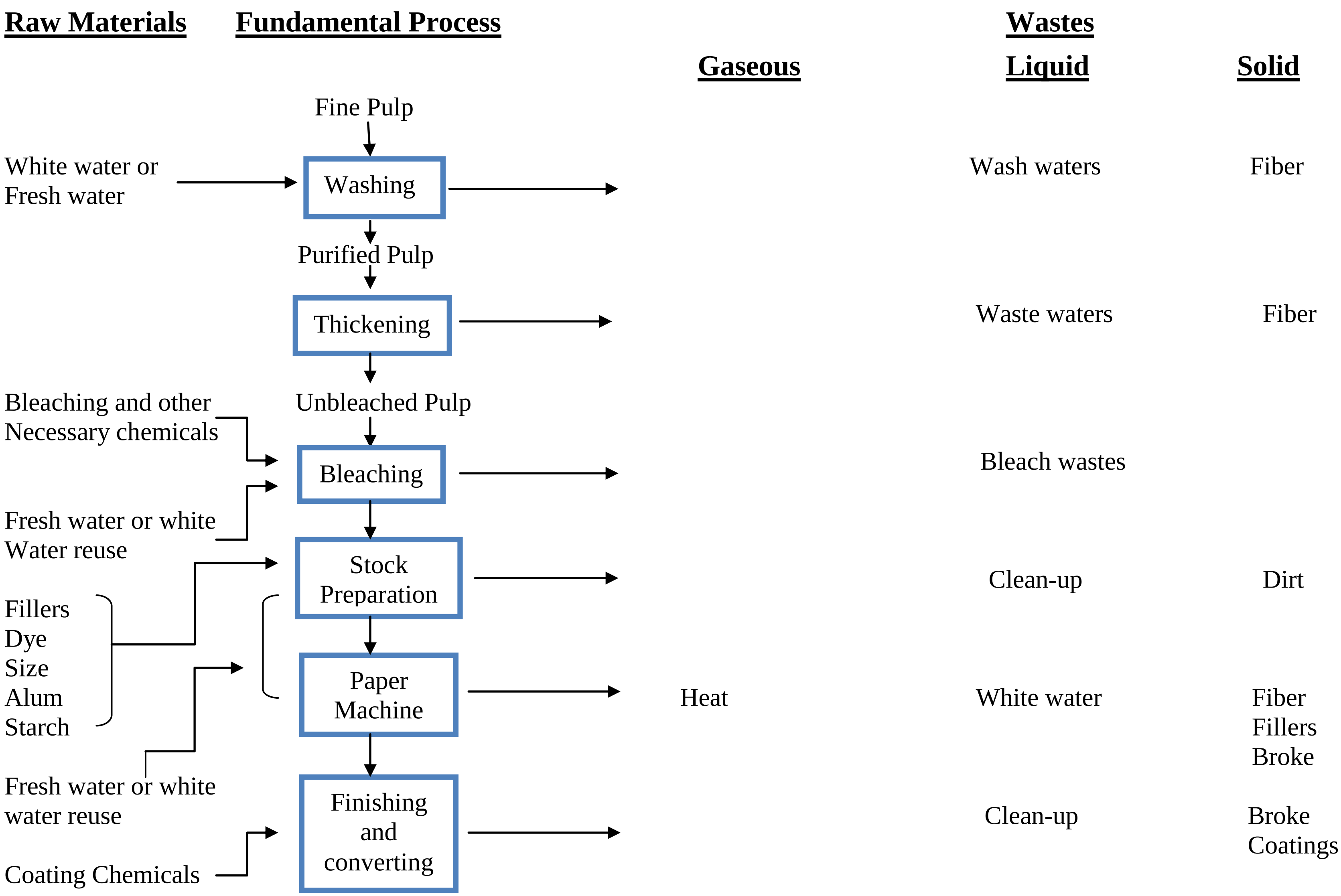


Fig 4.2 (b): Sources of wastes (gaseous, liquid and solid) from different processes in a typical Pulp and Paper (Part – II)

4.2 PROCESS DESCRIPTION at NAINI TISSUES LIMITED

NAINI GROUP OF INDUSTRIES came into existence with the incorporation of NAINI PAPERS LIMITED in 1995 as a public limited company. It was established under the dynamic leadership of the Group CMD Mr. Pramod Kumar Agarwal.

The Group produces 200 TPD environment friendly and good quality paper in order to serve the large consumers. The paper produced by NAINI has high levels of physical & optical properties. The writing & printing grade of paper is produced from the agricultural residues, namely bagasse and wheat straw, along with imported wood pulp.The group turnover in 2008-09 stood at Rs 241 crores.

Naini has become a strong brand in the paper market and strictly adheres to its key positioning line-

"Ethically Firm. Environmentally Strong."

NAINI GROUP OF INDUSTRIES has two companies under its umbrella:-

a) NAINI TISSUES LTD

b) NAINI PAPERS LTD

Naini Tissues Limited is the flagship company of the group and was incorporated in 2002. The plant produces 100 TPD writing & printing paper from agricultural residue, mainly bagasse and wheat straw. The turnover of the company in 2008-09 stood at Rs. 154 crores.

The plant is equipped with modern wet washing system, continuous digester and multi-stage bleaching. The paper machine is equipped with "Metso-make" pressurized head box, bi-nip press and kuster calendar.

The plant produces high bright MF paper with the brand name- "Naini Premium". GSM range is 52 to 110 and the machine deckle is 2790 mm.The finishing house consists of "Globe" rewinder and good quality sheet cutters.

Naini Papers Limited, incorporated in 1995, is the parent company of the group. The company produces 90 TPD writing & printing paper from agricultural residue, mainly bagasse and wheat straw. The turnover of the company in 2008-09 stood at Rs. 87 crores.

The plant is equipped with modern wet washing system, continuous digester, Oxygen Delignification and multi-stage bleaching. The paper machine is equipped with pressurized head box, bi-nip press and kuster calendar.

The plant produces both MF and MG varieties. GSM range is 54 to 220 and the machine deckle is 2920 mm.

Milestones Created and Achieved By Naini Group of Industries:

1) Setting up the first **"Soda Recovery Plant"** in an agro-based kraft paper mill in the country.

2) Producing 90% (ISO) brightness paper with agricultural residues- bagasse and wheat straw.

3) Installation of **Oxygen Delignification Plant (ODL)**.

4) Lowest water & process-chemical consumption in similar kind of industries.

Naini has celebrated its milestone by obtaining the three most prestigious accreditations– **ISO 9001:2000**, **ISO 14001:2004** & **OHSAS 18001:2007**.

M/s Naini Tissues Limited is located at 7th KM Stone, Moradabad Road, Kashipur (Distt. U.S. Nagar), Uttarakhand. The existing unit is producing 100 TPD of writing & Printing grade of paper and about 300 personnel are there to cope with the production rate round the clock. The raw material being consumed by the industry is Bagasse, Wheat straw, Elephanta Grass and imported softwood pulp. Caustic, starch and chemicals for sizing, retention, strength, filler & dyes etc. are also used. Rice husk & pith is used as fuel for boiler. To meet with the process requirement of water in the various section of the industry, underground well water is being used. The industry is installed with septic tanks and soak pits especially for domestic discharge whereas a full fledged effluent treatment plant of 10 MLD treatment capacity is in operation. To maintain a green cover, a large number and different varieties of trees and plants are planted along with the boundary of the mill and inside the mill as well.

Black Liquor generation of the mill is around 900 m^3/day with the characteristics of the same are shown in the *Table 4.1*. The Chlorine consumption in the mill is around 40 kg/ton of paper produced while the effluent generation from the bleaching section comes around to be 2200-2400 m^3/day. The Raw Material Consumption at Naini Tissues Limited is shown as per *Table 4.2* and same has been depicted graphically in *Figure 4.3*.

Table 4.1: Characteristics of Black Liquor in a Pulp and Paper Mill

Parameters	Range
Total Solids	8-10%
Chlorides	0.5-0.6%
pH	11-12
Residual Active Alkali (RAA)	4-6 gpl

Table 4.2: RAW MATERIAL CONSUMPTION (MT/ Month)

S. No.	Month	Bagasse	Wheat Straw	Hard wood Pulp	Soft wood Pulp	Elephanta grass
1	April	3434.606	4862.484	543.912	123.395	0.000
2	May	0.000	6660.766	591.773	113.950	0.000
3	June	574.886	7527.544	599.500	122.951	0.000
4	July	849.184	7182.198	328.516	113.860	0.000
5	August	5890.256	5148.614	351.100	116.667	0.000
6	September	7482.405	3799.258	245.030	199.390	0.000
7	October	1299.961	7060.897	299.371	155.203	489.335
8	November	0.000	6354.726	317.000	114.157	55.450
9	December	0.000	7084.959	187.559	97.508	700.315
10	January	2034.849	6805.765	0.000	164.696	58.340
11	February	9204.980	3476.265	0.000	102.526	0.000
12	March	0.000	8298.529	0.000	303.449	0.000
	TOTAL	**30771.127**	**74262.005**	**3463.761**	**1727.752**	**1303.440**

It can be seen from *Table 4.2* that Wheat Straw and Bagasse are the major raw materials used in different proportions depending upon the requirements of a product. Also, the other raw materials such as Hardwood Pulp, Softwood Pulp and Elephanta Grass are used in small proportions as per *Table 4.2* depending upon the quality of the final product required.

Fuel consumption in Naini Tissues Limited for the previous financial year is given in *Table 4.3* and same has been depicted graphically in *Figure 4.4*. It can be seen from *Table 4.3* and *Figure 4.4* that Rise Husk and Diesel are being used as a fuel in the boilers. The average monthly consumption of Rise Husk as per *Table 4.3* is about *4587 MT* while diesel average monthly consumption comes around *68 MT*.

Water Consumption in Naini Tissues Limited is given in *Table 4.4* while *Figure 4.5* shows the percentage distribution of the same. The total water consumption for previous financial year is around *2641700 KL* out of which *166427 KL* is contributed to boilers, *163785 KL* for cooling operations and rest is contributed to processing whereby water gets polluted & pollutants are easily biodegradable. As per *Figure 4.5*, the total contribution from boiler and cooling operations is around 12% while 88% is contributed to processing whereby water gets polluted and pollutants are easily biodegradable. The monthly average for the main product (writing and printing grade of paper) is around *3197.6 MT* as per *Table 4.5*.

Figure 4.3: Raw Material Consumption at Naini Tissues Limited

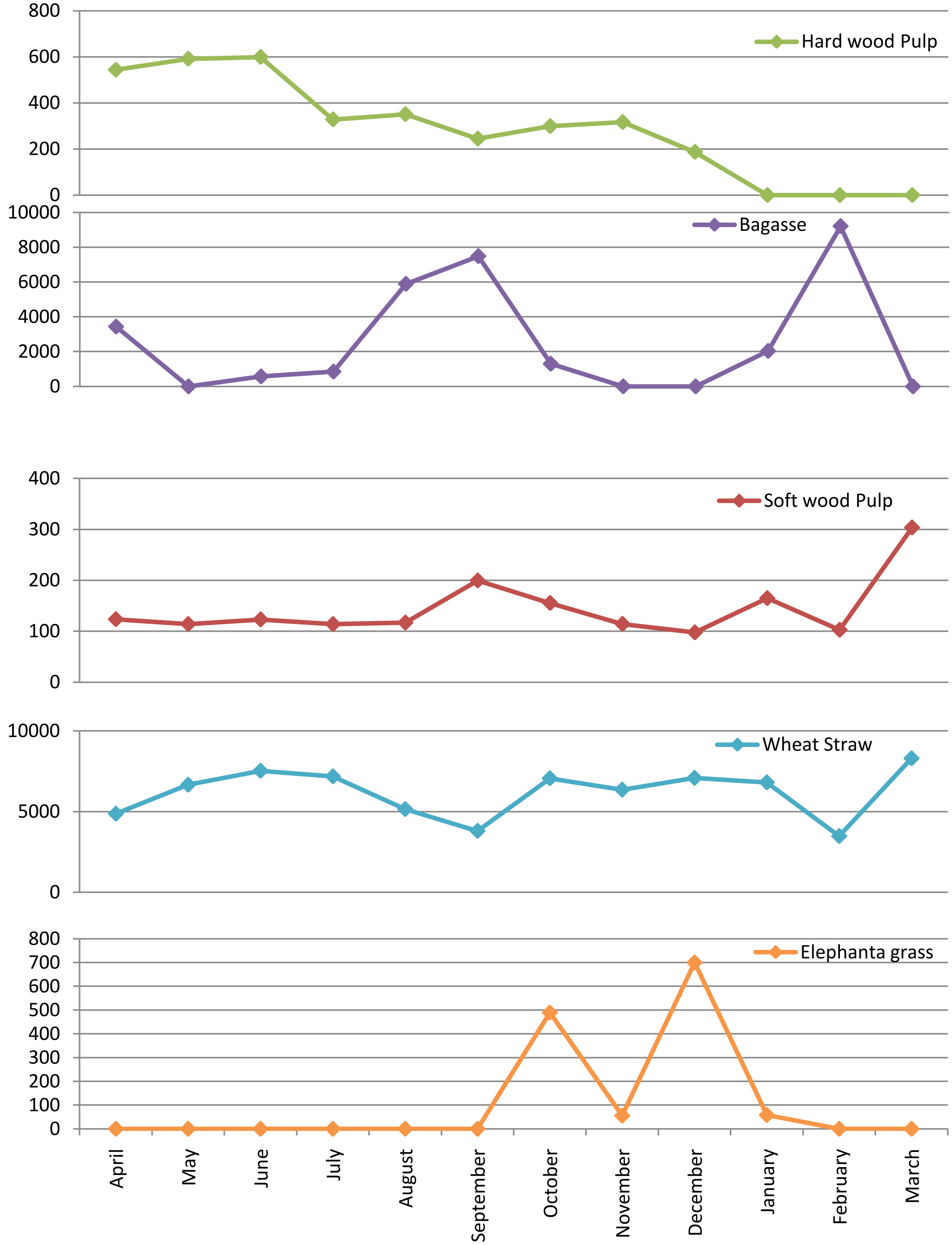


Table 4.3: FUEL CONSUMPTION (MT/MONTH)

Month	Rice husk	Diesel
April	4620.000	81.056
May	4612.000	95.859
June	4629.000	56.261
July	4755.000	94.598
August	4725.000	75.955
September	4800.000	33.620
October	4870.000	39.953
November	4113.000	29.576
December	4400.000	23.815
January	4498.000	50.664
February	4501.400	109.530
March	4518.000	132.422
TOTAL	**55041.400**	**823.309**

Figure 4.4: Fuel Consumption at Naini Tissues Limited

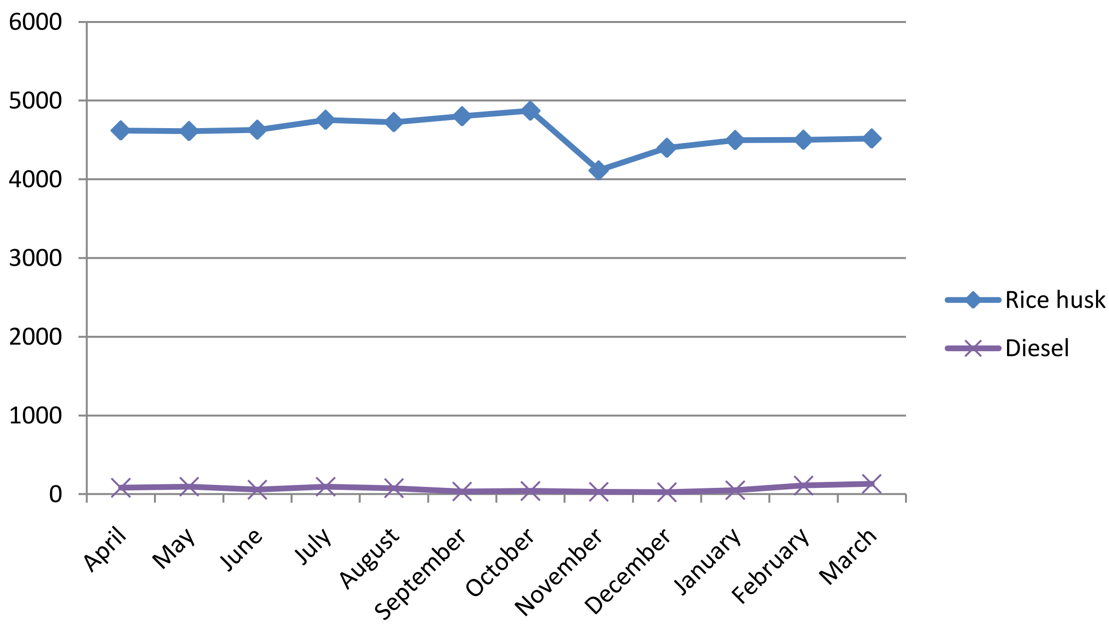


Table 4.4: WATER CONSUMPTION (Naini Tissues Limited)

Month	Boiler (KL)	Cooling (KL)	Processing whereby water gets polluted & pollutants are easily biodegradable (KL)	Total (KL)
April to March	166427	163785	2311488	2641700

Figure 4.5: Water Consumption Chart at Naini Tissues Limited

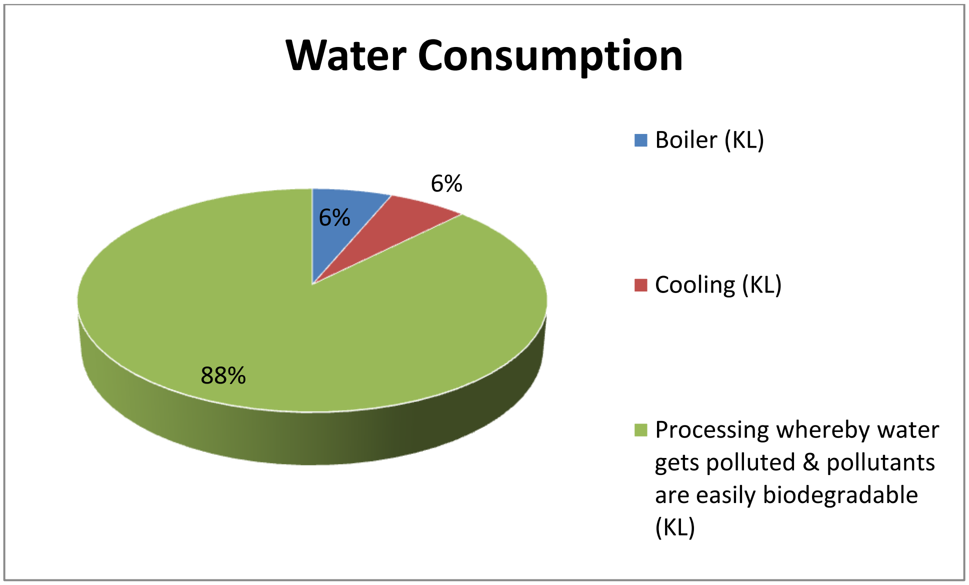


Table 4.5: PRODUCTION FIGURES (Naini Tissues Limited)

S. No.	Month	Main Product (Writing & Printing Grade of Paper) MT
1	April	3055.256
2	May	3134.56
3	June	3562.14
4	July	3243.039
5	August	3387.821
6	September	3120.189
7	October	3380.698
8	November	2819.548
9	December	3028.483
10	January	3131.862
11	February	3066.874
12	March	3440.682
	TOTAL	**38371.152**

Figure 4.6: Main Product (Writing & Printing Grade of Paper) MT (Naini Tissues Limited)

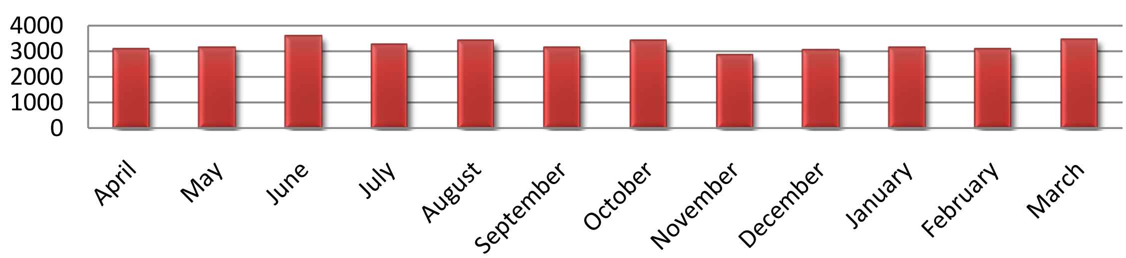


Table 4.6: SOLID WASTE GENERATION (Naini Tissues Limited)

S. No.	Month	ETP Sludge	Boiler Ash
1	April		
2	May		
3	June		
4	July		
5	August		
6	September		
7	October		
8	November		
9	December		
10	January		
11	February		
12	March		
	Total	**4694.6 MT**	**2226.8 MT**

All the solid waste generated are non hazardous in nature. ETP Sludge is used for card board manufacturing & boiler ash for land filling & as fertilizer in fields.

Solid Waste Generation for a year is given as per Table 4.6 that comes around to be 4694.6 MT for ETP Sludge while for boiler ash the figure is around 2226.8 MT. Hence, the monthly average consumption for ETP Sludge is 391.22 MT and the boiler ash generated monthly on an average basis comes to be around 185.6 MT.

4.2.1 PULPING PROCESS

Pulping process employed in Naini Tissues Limited, Kashipur comprises of 1 no. of Digestor with a capacity of 80 TPD of bleached pulp. The cooking time of the digestor is 20 minutes and the digestor is of continuous blow type. The quantities of raw materials that are to be used, during full production are as follows:

- Wheat Straw/Bagasse – 137 TPD
- Imported Wood Pulp – 25 TPD

Unbleached pulp production of the mill is found to be around 88 TPD with a Kappa Number in the range of 14-16.

(a) Bagasse and Wheat Straw Pulping

i. Raw Material Preparation

Bagasse is processed through de-pither where approximate 80 % of the total pith is removed. De-pithed bagasse is fed to wet washing system to wash out remaining juice and pith. De-pithed and washed bagasse is charged in continuous digester for cooking.

Wheat straw is also processed through separate de-dusting and wet washing system to remove sand, fines and other unwanted materials. Removal of these unwanted materials is beneficial to improve pulp quality, which result better strength properties of paper. De-dusted and washed wheat straw is charged in continuous digester for cooking.

The sand and the piths removed in the yard house is recovered and then used in the boiler house so as to reduce the consumption of the fuel (diesel) thereby reducing the overall operation cost of the mill.

ii. Continuous Cooking

Cooking is being carried out in continuous digester instead ofbatch digester to get soft and more uniform pulp so that bleaching chemicals demand can be reduced drastically to improve pulp strength properties and brightness.

Figure 4.7: Raw Material Yard House

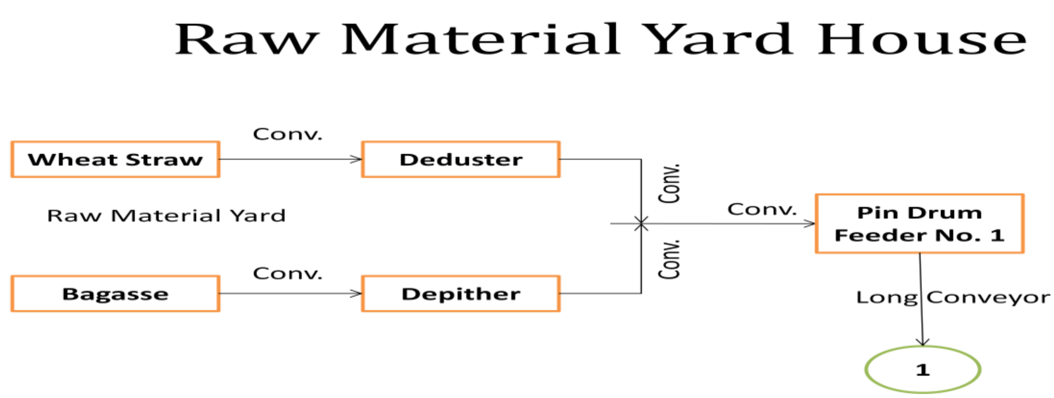


Figure 4.8 (a): Process Flow Diagram – (i)

The purpose of the cooking is to chemically dissolve the lignin from raw material in order to obtain bleachable grade pulp. The most suitable continuous digester for cooking of non-wood raw materials like wheat straw and bagasse is PANDIA DIGESTER which has been installed in the plant.

The main components are: -

- Metering Screw
- Pin drum feeder
- Equalizing Screw
- Screw Feeder
- Time Screw (Cooking Tube) No. 1 & No. 2
- Cold Blow Discharge

Raw material squeezing is done by a screw feeder after wet washing. During feeding the raw material is dewatered and homogenized.

The filtrate from the screw feeder is returned to the wet cleaning system. The digester blow back valve is placed just opposite the screw feeder with the shutdown system for emergency cases to avoid the blow out of the digester content via screw feeder.

The cooking liquor, a mixture of white liquor and black liquor is heated up and injected into the Intel chamber. Steam for heating up the raw material is added to the Intel chamber and to the digester tubes. Different cooking conditions are maintained for different type of raw material.

Cooking is carried out in two horizontal tubes equipped with variable speed screw which slowly convey the material to be cooked and which ensure a high filling degree of the tube volume.

After cooking, the pulp is cooled down by injecting cold black liquor into cold blow discharge. The pulp is blown out from the cold blow discharger into the top dome of the blow tank, from there the pulp drops into the blow tank itself and is diluted to pump-able consistency with black liquor.

The fresh water is heated upto 65 – 70 C^0 with blow tank flash steam and cooling of black liquor (CBD Dilution). This hot water is used for unbleached pulp washing to reduce soda loss in washing.

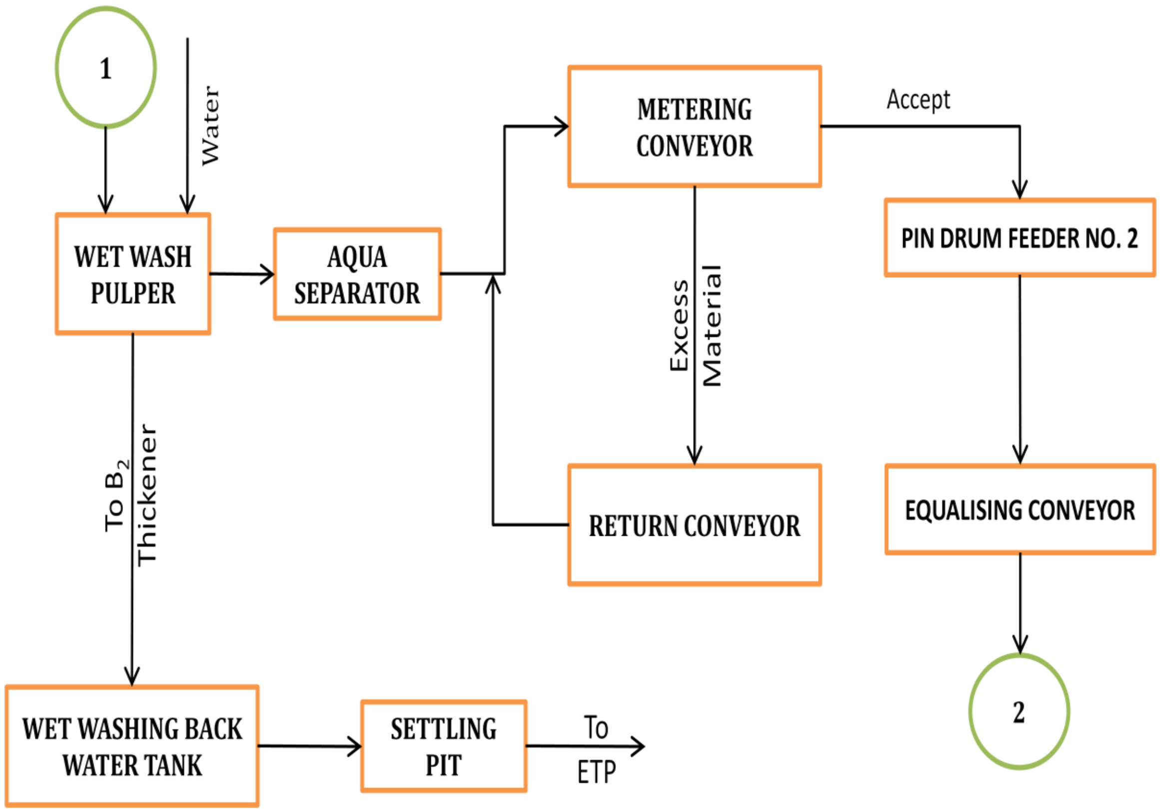


Figure 4.8 (b): Process Flow Diagram – (ii)

Figure 4.9: Wet Wash Pulping section (Pulper and Aqua Separator)

Figure 4.10: Metering Conveyor and Conveyor Belts

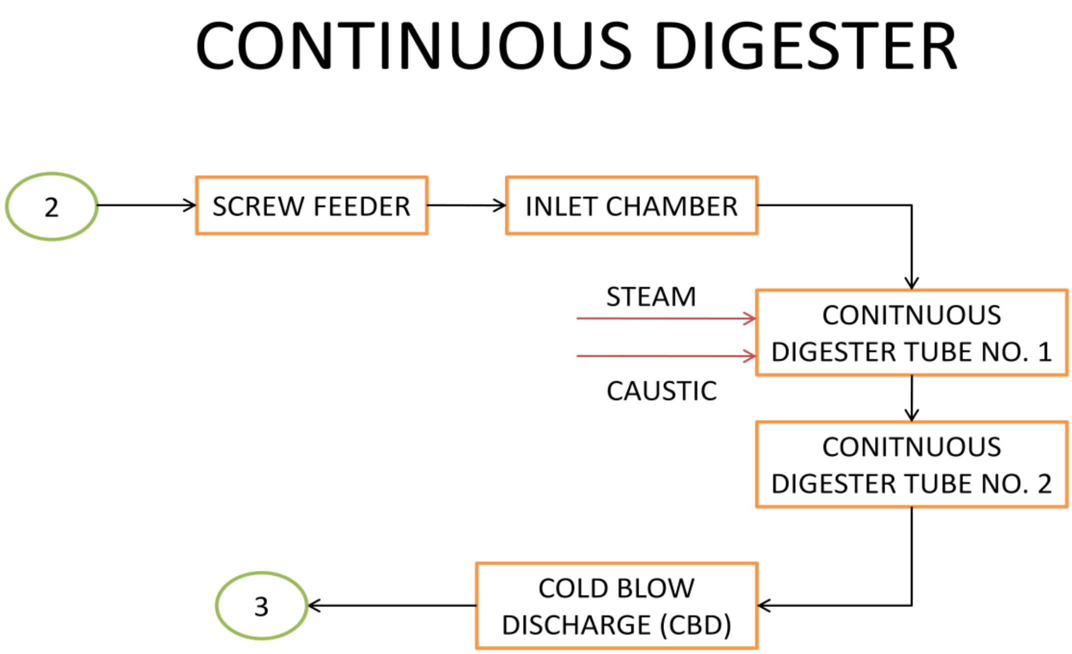


Figure 4.8 (c): Process Flow Diagram – (iii)

Figure 4.11: Continuous Digestor

Figure 4.12: Closed Blow Discharger (CBD)

Salient Features

- Less steam consumption per ton of pulp
- Less manpower requirement
- Low building cost and less space requirement
- Cold blow provision for improving pulp strength properties
- Gain in solid concentration of black liquor due to soft cooking
- Gain in yield due to less rejection and degradation of pulp for the same kappa no.
- Better process control due to PLC/DCS controlled system.
- Homogenous and soft cooking due to proper mixing of chemicals and steam and using of pulp aid with cooking liquor, resulting reduction in chemicals demand in bleaching.

iii. Unbleached Pulp washing , refining , screening and cleaning

Vacuum washers are used for unbleached pulp washing which is collected in a blow tank from continuous digester. Pulp from blow tank is processed through vibrating screen and then 4 - stage counter – current washing. Uncooked pulp (reject) is separated from pulp by vibrating screen.

A refining, screening and cleaning unit is situated between third & fourth washer to clean and to make the pulp homogeneous. Pulp from fourth stage brown stock washer is collected in a unbleached storage tower. Excess Black liquor from first brown stock washer seal tank is sent in soda recovery section.

iv. Bleaching and Washing (Partially chlorine free Bleaching C – Ep – H – H)

The mill is adopting C – Ep – H – H bleaching sequence instead of conventional bleaching sequence i.e. C - E – H – H. In this sequence chlorine demand is reduced by introducing hydrogen peroxide in alkali extraction stage (Ep).

Washed and cleaned unbleached pulp is treated with elemental chlorine in an upward flow tower at ambient temperature and 2.8 – 3.0 %, consistency. The bleaching conditions like pH, temperature, retention time, chemical dosing as per shade etc, are maintained in each stage of bleaching sequence. Washing is also carried out after each reaction tower. A cleaning unit is situated between final reaction tower and washer i.e. before hypo – washer no. 2. Finally the washed and bleached pulp is collected in a storage tower and then supplied to stock preparation as per paper machine demand.

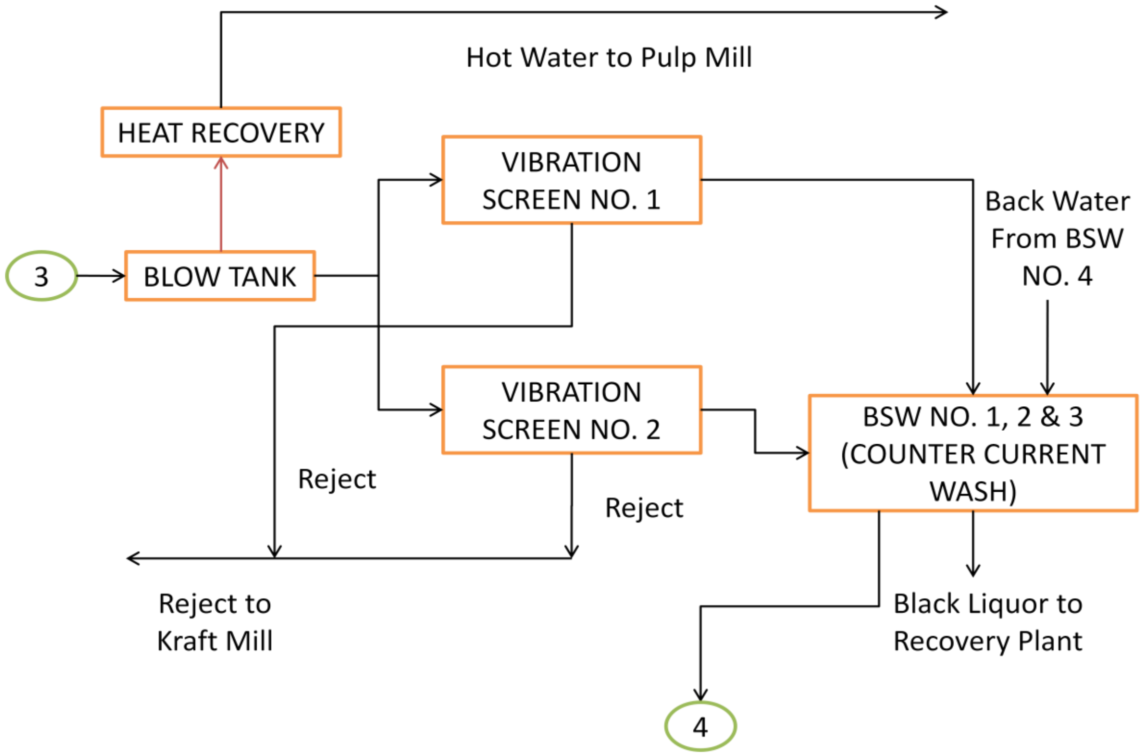


Figure 4.8 (d): Process Flow Diagram – (iv)

To reduce the fresh water consumption and effluent generation the paper machine encases back water is used in the washing shower of washers after proper clarification in mark – save-all and filtrate of chlorination stage for unbleached pulp dilution before feeding to chlorination stage.

Salient Features

- Final pulp brightness 82-83% against 79-80% as ISO in conventional bleaching sequence.
- About 1.5 – 2.0% reduction in chlorinated chemicals consumption by introducing Hydrogen peroxide.
- Improvement in brightness and its stability.
- Gain in strength properties.
- Reduction in pollution load.

Figure 4.13: Pulp Bleaching Operation

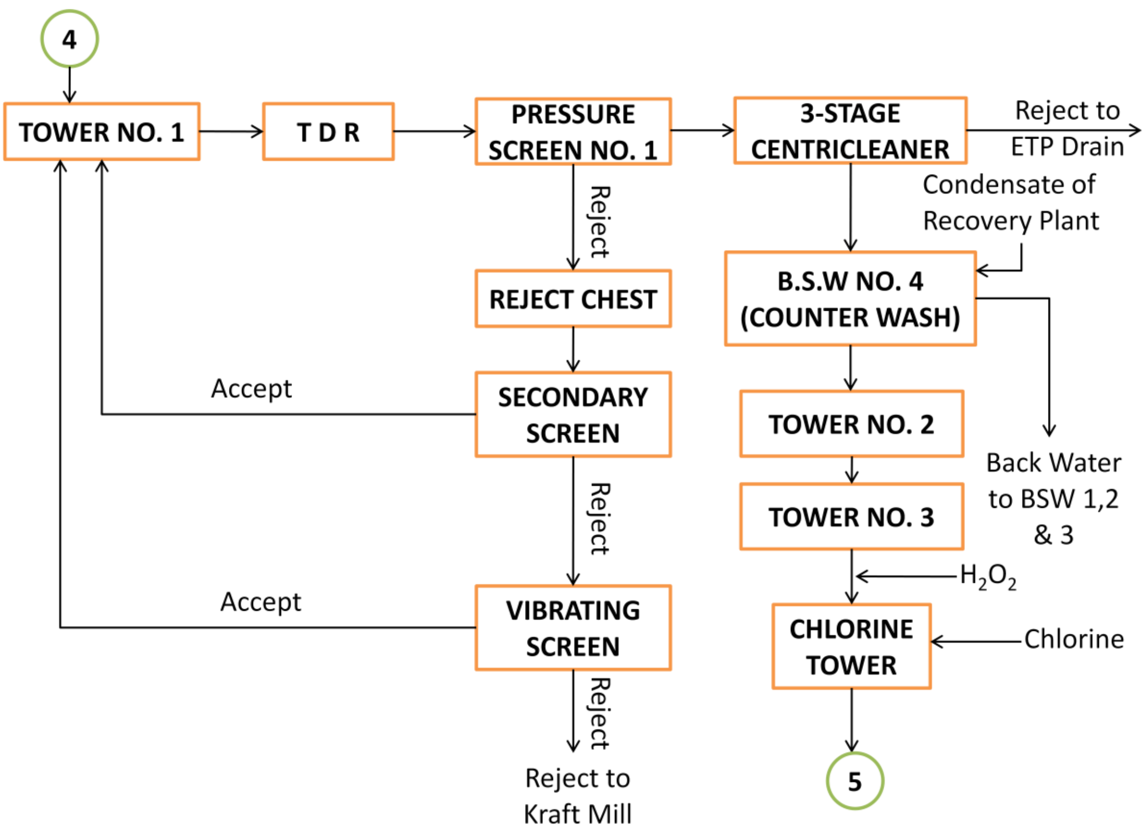


Figure 4.8 (e): Process Flow Diagram – (v)

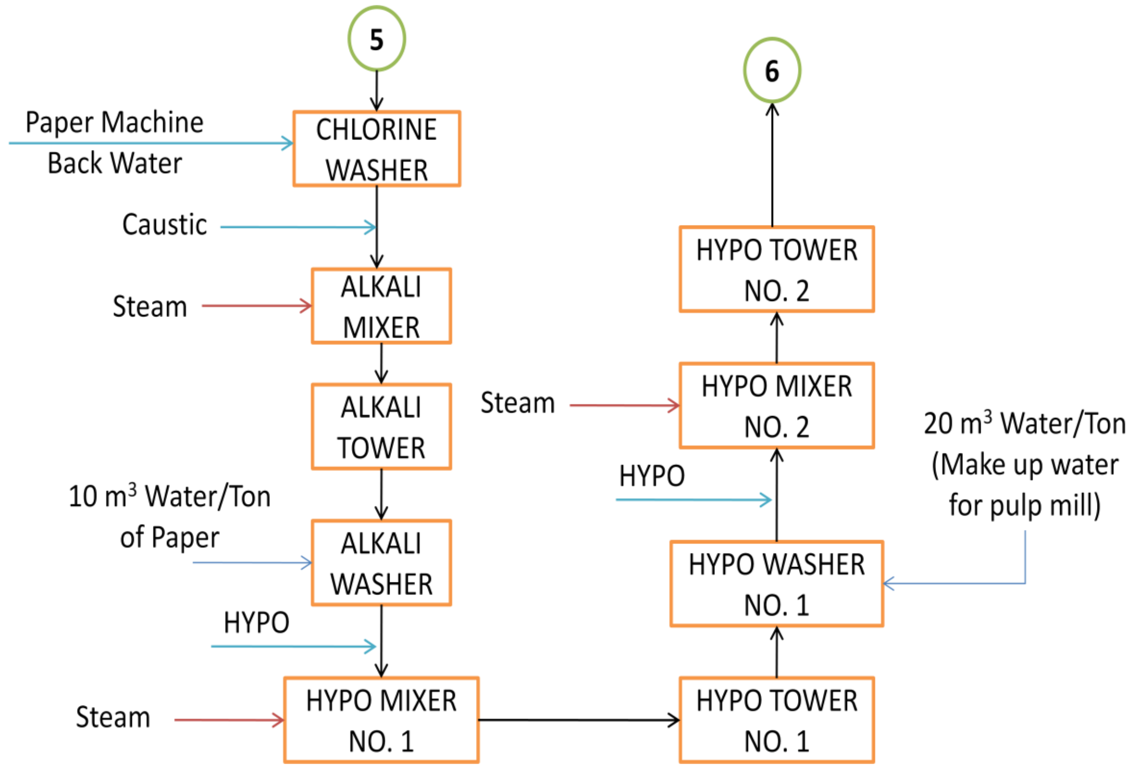


Figure 4.8 (f): Process Flow Diagram – (vi)

(b) Wood Pulp Pulping

Wood pulp is received in sheet form and treated as long fiber pulp, sheet are charged in pulper and after proper slushing, pulp is dumped in a chest from where pulp is processed through tri-disc refiner to maintain required freeness. Refined pulp is stored in refined pulp chest.

4.2.2 STOCK PREPARATION

This is the primary stage of paper making. Different type of pulp is mixed in stock preparation in different proportion as per the quality of paper. Other additives like rosin, alum, whitening agents, dyes, wet end additives and fillers are also added here in the pulp. Now this stock is ready for paper manufacturing. Stock is pumped to paper machine head box via machine chest and 3 stage centri-cleaners.

Broke pulp from finishing house and paper m/c is stored in a separate chest which is blended in the mixing chest in small proportion on continuous basis. Couch pit pulp from couch thickener and under flow of mark – saveall is also mixed in machine chest as per availability.

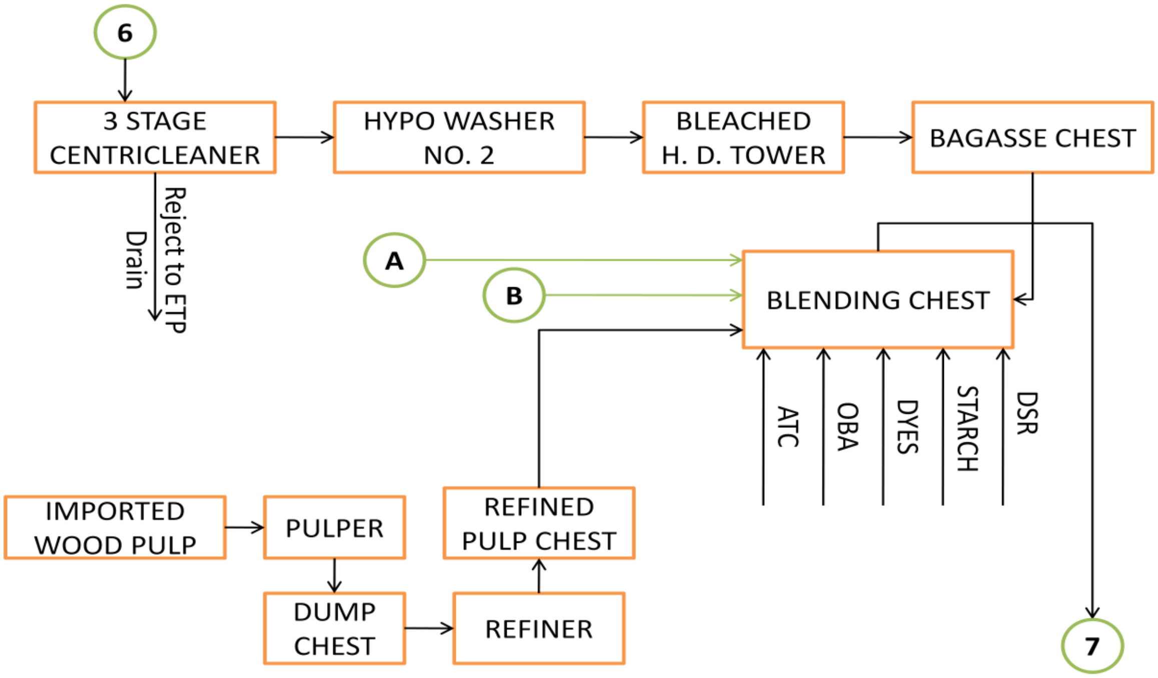


Figure 4.8 (g): Process Flow Diagram – (vii)

Figure 4.14: Stock Preparation Area

4.2.3 PAPER MAKING

The prepared stock from stock preparation is pumped to paper machine head box after diluting it with back water. This dilute suspension of fibers and water is spread over synthetic forming fabric uniformly through head box. This synthetic forming fabric is endless perforated/ messed belt. It remains rotating according to machine speed. Here the sheet formation takes place and water starts drain out from the pulp suspension flows on the endless perforated forming fabric. This drained water is called as back water. It is continuously diluted the stock which is forwarded from machine chest.

On the synthetic forming fabric, when the drainage of water through gravity reduces then water is removed by sucking from the pulp suspension by means of vacuum. The vacuum is applied by providing number of suction boxes beneath the synthetic forming fabric. The operating parameters are maintained and monitored continuously. In the end of sheet forming process the paper formed is called as web and it still remains quite wet.

In second stage water is removed by passing the web between two rotating rolls along with press felt. Here, when the web is pressed between rolls, the water squeezes out and felt absorbs it. This process of pressing is in two stages. The water absorbed by the felt is again sucked through vacuum. Here the essential operating parameters are maintained regularly.

Now after completing the water removal process through pressing, the remaining water present in paper is removed by evaporation through drying. In this process the paper is passed over steam heated dryers. These dryers are continuously heated by injecting steam inside it. Here the paper is dried gradually. These dryers are also rotating according to machine speed. The temperature of dryers in maintained and monitored continuously. Here the paper is dried upto its final dryness. Before reeling the paper on spool, it is calendered for smoothness and evenness.

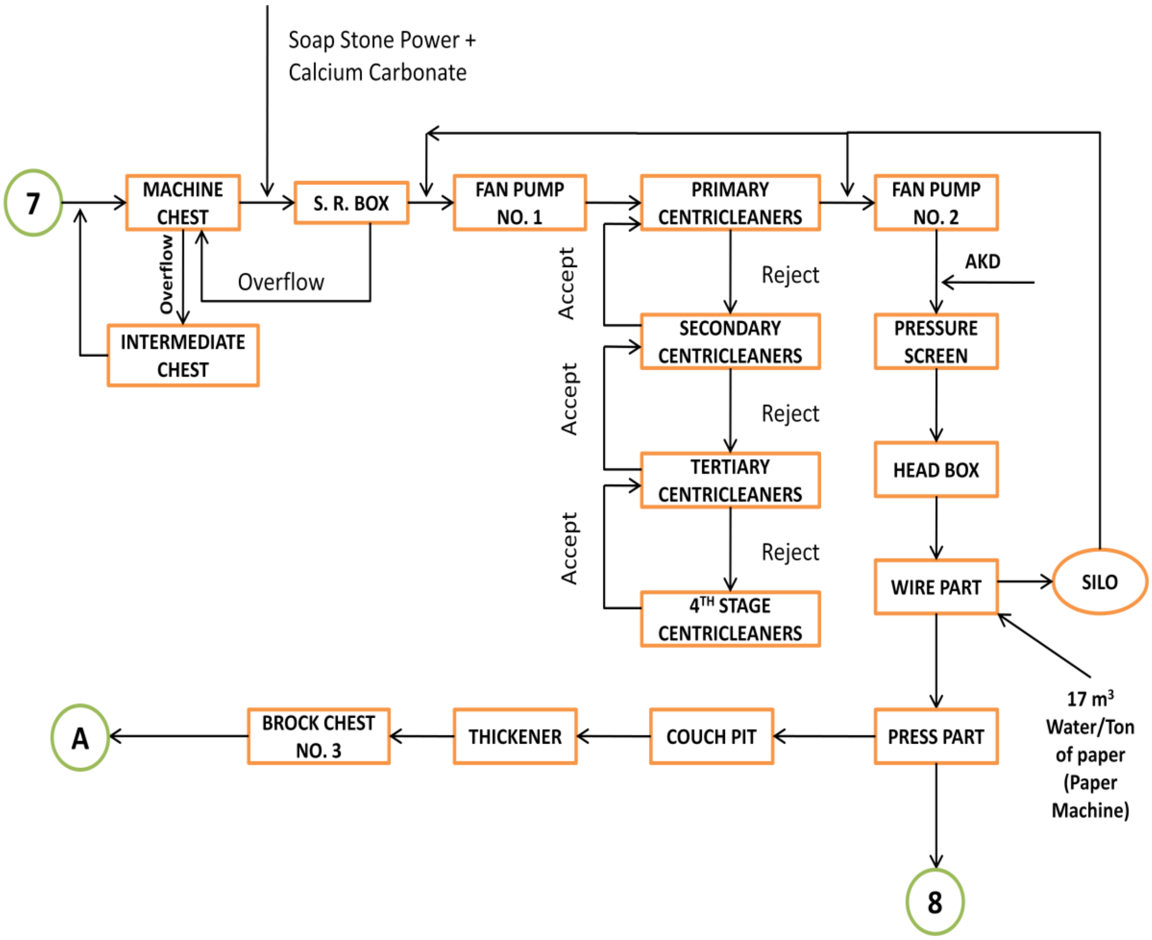


Figure 4.8 (h): Process Flow Diagram – (viii)

4.2.4 PAPER CONVERTING, FINISHING AND PACKING

The converting process of paper comprises in two operations:

- Sheeting
- Rewinding

In sheeting process the paper rolls taken out from pope reel and loaded on duplex sheet cutter. The paper cut into different specified sizes on this machine and it is further sent to finishing section. In finishing section the cut sheets are inspected manually to remove any defective sheet. Now by counting the reams of 500 sheets are made. These reams are packed into wrapper and then into hession in the form of bundle. The paper in the form of bundles is ready to sold and same is sent to godown for dispatch.

In rewinding process, the paper roll is again unwinded and rewind on rewinder into small size reels of specified sizes. The defective paper is removed and breaks of paper in paper roll are joined and pasted properly. The small reels are again wrapped and packed in wrapper and hession and finally sent to godown for dispatch.

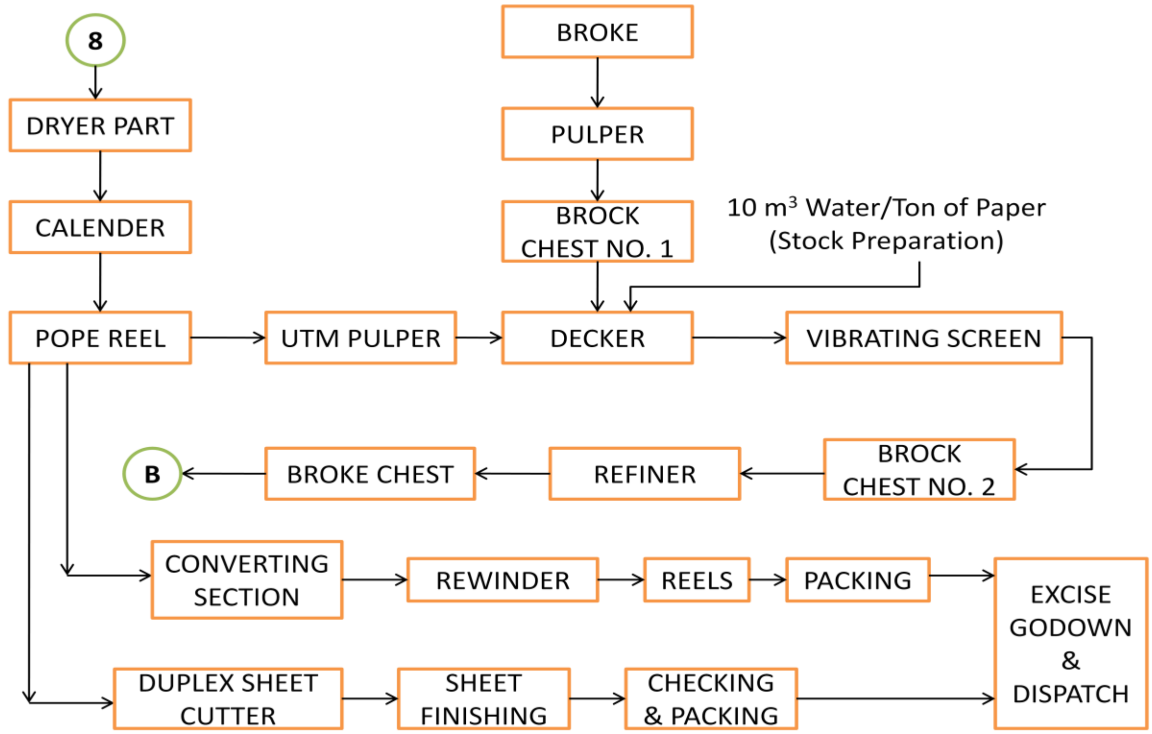


Figure 4.8 (i): Process Flow Diagram – (ix)

Figure 4.15: Paper Finishing House

CHAPTER 5

MANAGEMENT AND QUALITY PRACTICES ADOPTED

5.1 SODA RECOVERY PLANT

Two types of effluents are being generated in the integrated pulp and paper plant i.e. black liquor and mill water. Black liquor which is highly polluted is being used in soda recovery plant to produce value added product Sodium hydroxide or Sodium Carbonate. Less polluted mill water is treated in conventional effluent treatment plant to achieve the Pollution Control Board norms of final discharge.

M/s Naini Tissues Ltd. has installed a Soda Recovery Plant to produce Sodium Carbonate from black liquor. The Soda Recovery Plant can be divided in two parts as given below: -

- **Multiple Effect Evaporator (To Concentrate Black – Liquor).**
- **Cope Land Fluidize Bed Reactor (To Incinerate Black Liquor)**

Figure 5.1: Soda Recovery Plant at Naini Tissues Ltd., Kashipur

Multiple Effect Evaporator:- (Two Streets)

Evaporation is done in long tube multiple effect evaporators (6 – Effect). The low pressure steam (3–3.5 kgs/ cm^2) is being used from turbine exhaust as heating media in 1st – effect and weak black liquor feeding in 5th effect. Black liquor and vapour flow in the system in counter – current as shown in the flow diagram except 6th effect where vapour and liquor flow in the same direction. The liquor produced is called semi – concentrated black liquor is collected in separate tanks. Vapours from last body (6th effect) are condensed in a surface condensor where 680mm of Hg vacuum is created with the help of a vacuum pump.

Foul condensate and condensate of live steam are used in pulp mill for unbleached pulp washing and in boiler house for steam generation respectively. Evaporation plant is capable to concentrate Black liquor from 9% to 24% at evaporation rate of 75 TPH and steam economy 4.2 : 1.

- **Cope Land Fluidize Bed Reactor (F.B.R.):- (Two Nos.)**

The combustion of semi – concentrated black liquor is completed in a Reactor. We have selected Fluidized Bed Reactor, which is more suitable for agro – base black liquor which have low calorific value and higher viscosity.

The SCBL is further concentrated from 25% dry solids to 45% in a direct contact ventury scrubber by hot flue gasses coming from fluidized bed reactor (F.B.R.). Fluidized bed reactor operates at lower temperature of only (680 – 700^0 C) and produces pellets of Sodium Carbonate on continuous basis.

The FBR consists of a chamber with the wind box at the bottom which contain the orifice plate and the air nozzles. The orifice plate in the wind box ensures uniform distribution of fluidizing air. A blower supplies the air which is preheated with oil in the initial startup. Only The fluidizing air also supports the bed materials.

The bed can be divided into lower bed and upper bed levels which can be distinguished by bed material density and temperature. The temperature of the lower bed is higher than that of the upper bed. The temperature profile of the reactor is : wind box 80^0 C, lower bed 680^0 C - 700^0 C, upper bed 675^0 C, and free board 620^0 C.

The upper zone of the reactor is known as the free board. To keep the temperature of the free board below the melting point of Soda ash, water is sprayed into the free board from the reactor top.

Partially dried and charred materials move downwards the fluidized bed zone. The bed materials are kept in suspension by the fluidized air. The bed temperature is maintained at 680 - 700^0 C. Pellets of soda ash are taken out through the side discharge nozzles of the bed at a predetermined rate so that the bed level is more or less maintained. The rate of discharge of pellets is controlled by the rate of black liquor solids firing at the top of the FBR.

5.2 QUALITY CONTROL POLICY & PRACTICES

Naini Group of Industries are committed to establish ourselves as leaders in agro-based paper mills by supplying consistent quality product and prompt services to the customers, which they endeavor to achieve by:

- constantupgradation of technology and adopting good management practices.

- achieving maximum productivity by means of improvement in operational performance.
- promoting team work and good brand image.
- complying all pollution control norms using eco-friendly practices.
- ensuring highest level of safety.
- complying with all the requirements of ISO 9001:2000 and continuous improvement in effectiveness of quality management system.

Quality Control Practices:

NAINI maintains the highest level of product quality at par with international standards and has a well established quality control department to ensure the same. Quality is ensured right from the stage of purchase of raw material to the finished product. Strict quality checks are performed at each and every stage of manufacturing. The finished paper is finally tested as per the standard norms and sent to excise storehouse only after clearing quality checks.

The quality control activities are divided in following parts –

- Input quality control
- In-process testing
- End-Product Inspection
- Product Development

5.3 ENVIRONMENT, HEALTH AND SAFTEY POLICY

NAINI Group is strongly committed to develop and operate a safe, healthy & clean environment while manufacturing writing & printing grade of paper.EHS procedures are designed to protect human health and prevent degradation of the environment by minimizing the adverse effects of Naini's operations while ensuring compliance with applicable legal requirements.

Naini's EHS program management consists of the following areas duly complied by the Group:

- Prevention of ill-health among workers.
- Prevention of pollution.
- Interests of all stakeholders.
- Integrating safety, health & environment matters in all existing activities and future planning.

- Continuous improvement in the effectiveness of EHS by improving process work practices and risk minimization.

Naini Group constantly strives for:

- Awareness among employees, society and other stakeholders about environment protection, minimization of waste, wise use of energy, water & other natural resources.
- Enhance awareness, skills and competence of our employees and contractors so as to enable them to demonstrate their involvement, for sound EHS performance.
- Allocating sufficient resources as required for the implementation of this policy.
- Preventing release of pollutants to the atmosphere, land or water.
- Minimizing the amount and toxicity of generated waste.

NAINI group has been conferred with many awards and recognition for translating its good qualities into action keeping the environment friendly processes intact.

NAINIGroup has been bestowed with the following awards:

Environment Management Award - 2007:

NPL was given the first Environment Protection Award by Uttarakhand Environment Protection and Pollution Control Board (UEPPCB) in 2004. NPL was the first agro-based kraft paper mill in the country to install ***"Soda Recovery Plant" (Cope-Land Process).*** After its success, Central Pollution Control Board (CPCB) made it mandatory for all the agro-based kraft paper mills in the country to install this plant.

Environment Protection Award - 2005:

NTL was awarded ***Environment Protection Award*** in 2005 by UEPPCB for the commendable work done in Effluent Treatment Plant (ETP). The effluent discharged from the mill meets the stringent pollution control norms.

Water Management Award - 2007:

NTL was conferred with the ***"National Award for Excellence in Water management"*** in 2007 by Confederation of Indian Industries. This award is in recognition to the monumental work done by the plant to reduce the utilization of fresh water. The fresh water consumption in both the group companies is only 70 KL per Ton of paper.

5.4 PAPER RESEARCH AND DEVELOPMENT LABORATORY

There is a dedicated R&D lab in Naini Tissues Ltd. which is equipped with all the latest instruments to measure the different properties (optical and physical properties) of the final product i.e. writing and printing grade paper, hence providing the best product available to the market and to the consumers. The tests are carried out on the final product on a continuous basis by laboratory personnel to continuously check the grade of paper produced. The tests are carried out to measure the optical and physical properties of the final grade of paper prepared.

Figure 5.2: Paper Research and Development Laboratory at Naini Tissues Limited

Following test equipments are already being used in the Paper R&D laboratory to test the quality of the final grade of paper produced:

1. **ELREPHO –** It's a brightness and colour tester. It is also used to measure the opacity of the final grade of paper which is generally kept greater than 85%. The company which makes this instrument is Lorentzen & Wettre (L&W). The instrument is capable of many tests but company has automated some programs that are essential for the testing.
2. **Tensile Strength Tester –** This machine Is used to measure the tensile strength of the paper. The strength is calculated on two different configurations i.e. machine

and Cross. It is also used to measure the breaking length of the paper (it's the length at which the paper breaks due to its own weight.)

3. **Tearing Tester –** This instrument is used to measure the tearing strength of the paper.
4. **Stiffness Tester (Make – Lorentzen & Wettre)** – This is used to measure the stiffness of the paper so that it should not fold by itself when held upright. The stiffness is calculated in milli – newton (mN).
5. **Folding Endurance Tester –** This instrument is used to measure the folding endurance of the paper produced (the paper is checked for the crack formations when it is folded turn by turn. Generally, the currency notes are made such that they won't form cracks when they are even folded multiple times and the same has been checked for the final grade paper so as to maximize the product life).
6. **Water Penetration Tester or Cope Tester –** This instrument is used to measure the absorbance of the paper made so that the ink should not spread over it when it is being used for writing or printing. For a good paper quality, the paper should not absorb much of the water when it is applied to it. In this method, standard IS method is being used in which there is a cylindrical bucket clamped on a small axle. The bucket has an area of about 100 cm^2. 100 ml of water is taken into the bucket and then the paper to be tested is clamped over the top of the bucket and covered with the top cover. Then the bucket is reversed and allowed to stand in this position for about 45 secs after which the paper is taken and bailed out of the moisture with the help of a bailer. Now, the amount of water that is retained in the fibers is calculated as the final weight which includes the moisture the paper has retained. Final minus initial weight gives us the weight of the moisture retained and hence the standards are checked against the value obtained.
7. **Precision Thickness Micrometer (Dead Weight Type) –** This instrument is used to measure the thickness of the paper made. The quantity of the paper sold is in GSM (Gram per meter square)
8. **Smoothness Tester (Make – Bendtsen) –** This is used to measure the smoothness of the paper with the help of an arrangement that uses the air flow over the surface of the paper. If the surface is absolutely smooth then it would show a reading of 0 while if rough surface is encountered then it would give a reading in ml/min.
9. **Core Compression Strength Tester –** This instrument is used to measure the strength of the core on which the huge reels of paper are stored so that it won't collapse under the pressure of the weight of the reel thus formed.

10. **Bursting Strength Tester –** This is basically a packing material tester (wrapping material tester) to test the bursting strength of the wrapping material of the final product so that it won't cut during loading/unloading or during transport.

5.5 WASTEWATER GENERATION AND MANAGEMENT

Pulp and paper mills are water intensive industry and in India, the consumption of water is quite high in this industrial sector because of the use of obsolete technology in the production of paper. Also, due to increased consumption of water, wastewater generation is quite high in this sector as the pulp and paper mills generate high amount of wastewater in almost all of the various sections within the pulp and paper mill. However, the pulp and paper mills in India are now adopting innovations in the manufacturing processes by modifying some of the conventional processes/technologies such as use of continuous digestor of pulping, replacement of conventional brown stock washers and modification in bleaching operations as observed in case of Naini Tissues Limited. Naini Tissues Limited is trying relentlessly to have a zero discharge policy thereby making a firm statement in the industry. Water and Wastewater generation sources at Naini Tissues limited were studied and a water/mass balance of the whole pulp and paper mill operations was made and is as per *Figure 5.1 (a), (b), (c), (d), (e) and (f)*. The fresh water consumption of the whole plant was found to be 2515 m^3 which is being taken up by bore wells (Ground Water).

<u>Water Consumption</u>

Fresh water consumption (From Bore Wells) – 2515 m^3

Hot Water (from recovery) – 900 m^3

Total Water Consumption – 3415 m^3

So, a total of **31 m^3/MT** of water is being consumed in production of paper.

Boiler – 4 m^3/MT

Chemical Recovery – 5 m^3/MT

Hence, a total of **40 m^3/MT** water is being used including Boiler and Chemical Recovery section of the pulp and paper mill.

Effluent Generation

The total amount of effluent generation at ETP inlet is about **5688.0 m^3/day** out of which about **3500.0 m^3/day** is being recycled back to be utilized in the manufacturing process itself so as to minimize the final disposal of effluent and also the fresh water consumption is reduced. The total amount of effluent being disposed off is about **2188.0 m^3/day**.

The wastewater generation sources at Naini Tissues Limited are as follows:

1. Wet Washing Operation
2. Refiner, Primary Screen and Centricleaner
3. Brown Stock Washer No. 1 (To Chemical Recovery Plant)
4. Chlorine Washer
5. Alkali Washer
6. Hypo Washer No. 1
7. Hypo Washer No. 2
8. Centri-Cleaner Reject (before Paper Machine Section)
9. Paper Machine Reject

Evaporation Losses during the manufacturing process of paper are as follows:

1. Blow Tank – 110 m^3 steam
2. Cooling Tower – 2 m^3
3. Dryer Section – 156.47 m^3

Recycling is also being adopted at various sections of pulp and paper mill such as 1491 m^3 black liquor is recycled from BSW Seal Tank No. 1 to Closed Blow Discharger (CBD) for dilution. In addition to the aforesaid, back water from BSW No. IV Seal Tank is being recycled partly to BSW No. III and mostly to Refiner, Primary Screen & Centri-Cleaner while other sections adopting recycling as per Table 5.1 describing the sections from which the water is being recycled with quantities mentioned against the sections where the back water is being reused.

Table 5.1: Recycling options adopted at Naini Tissues Limited

Sections	Recycled to	Quantity, M^3
BSW* No. I Seal Tank	Caustic Tank Closed Blow Discharger (CBD)	262 1491 (Black Liquor for dilution)
BSW* No. IV Seal Tank	BSW No. III Refiner, Pr. Screen and Centri-Cleaner	688 5652
Alkali Washer Seal Tank	BSW No. I	660
Hypo Washer No. II Seal Tank	Alkali Washer Hypo Washer No. II	350 350
Clear Water Tank	Chlorine Washer Alkali Washer Hypo Washer No. I Hypo Washer No. II Broke Pulper	600 600 600 600 216.3
Excess Back Water Tank	H.D. Tower No. II Blending Chest	1336 1063

Here, BSW refers to Brown Stock Washer

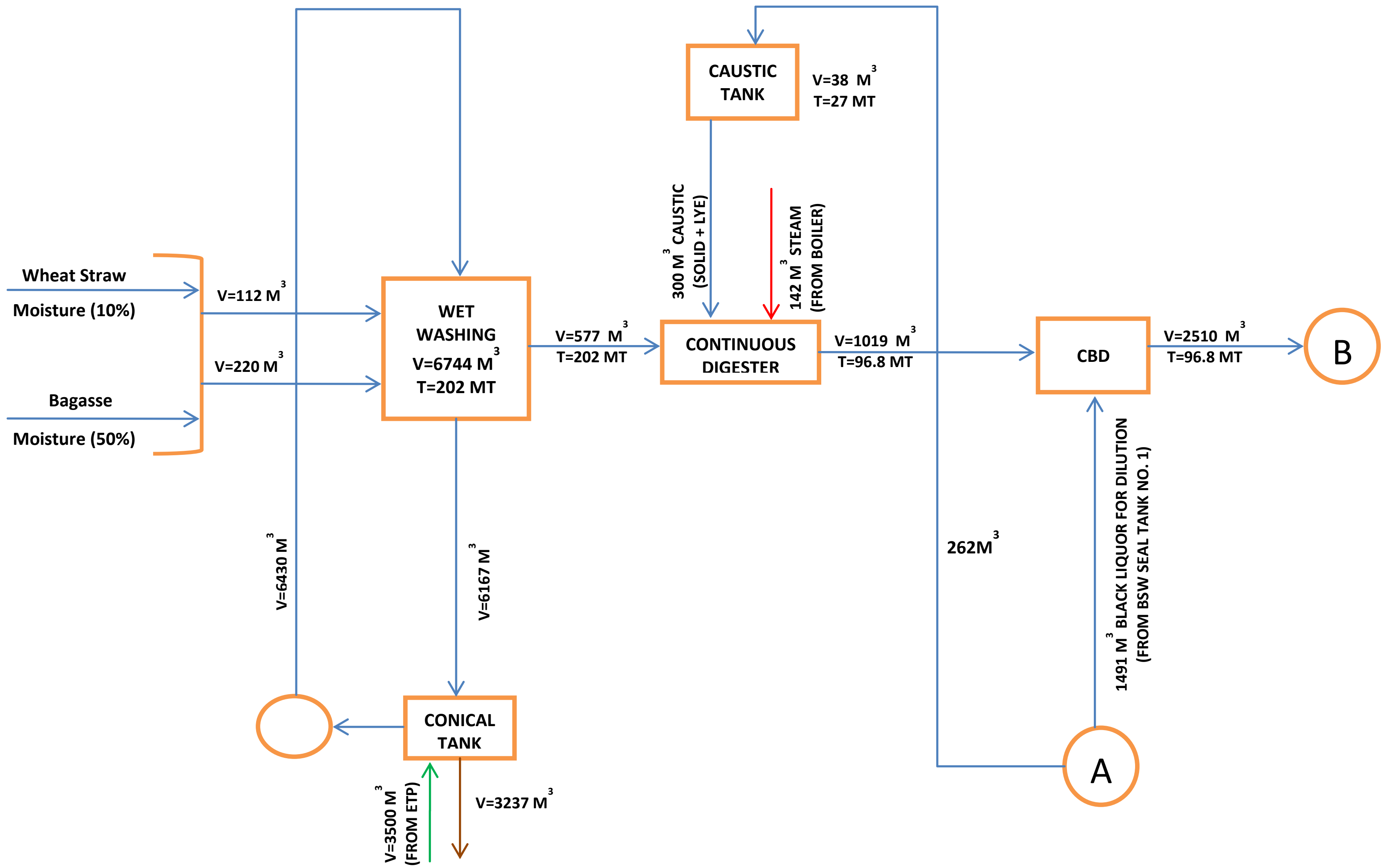


Figure 5.3 (a): Water/Mass Balance Diagram – (i)

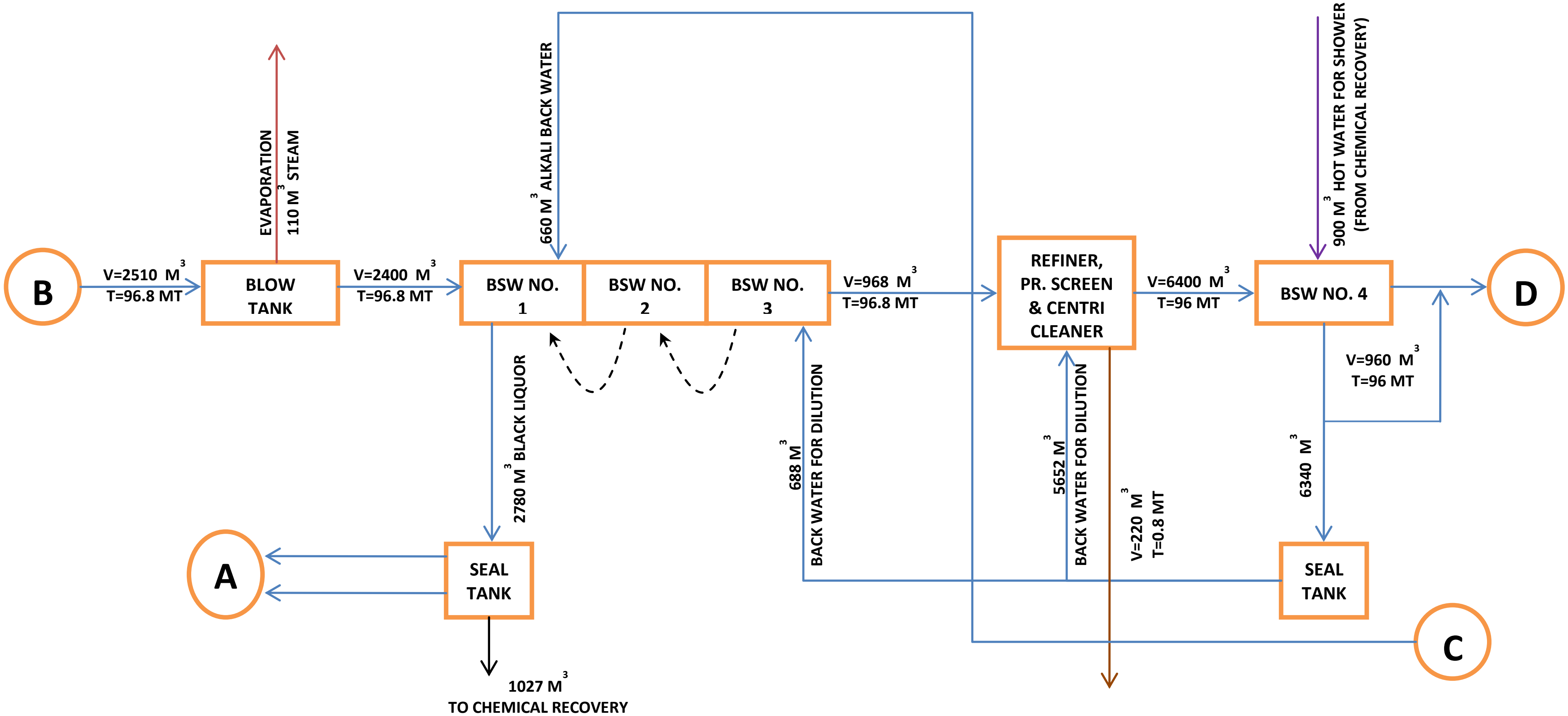


Figure 5.3 (b): Water/Mass Balance Diagram – (ii)

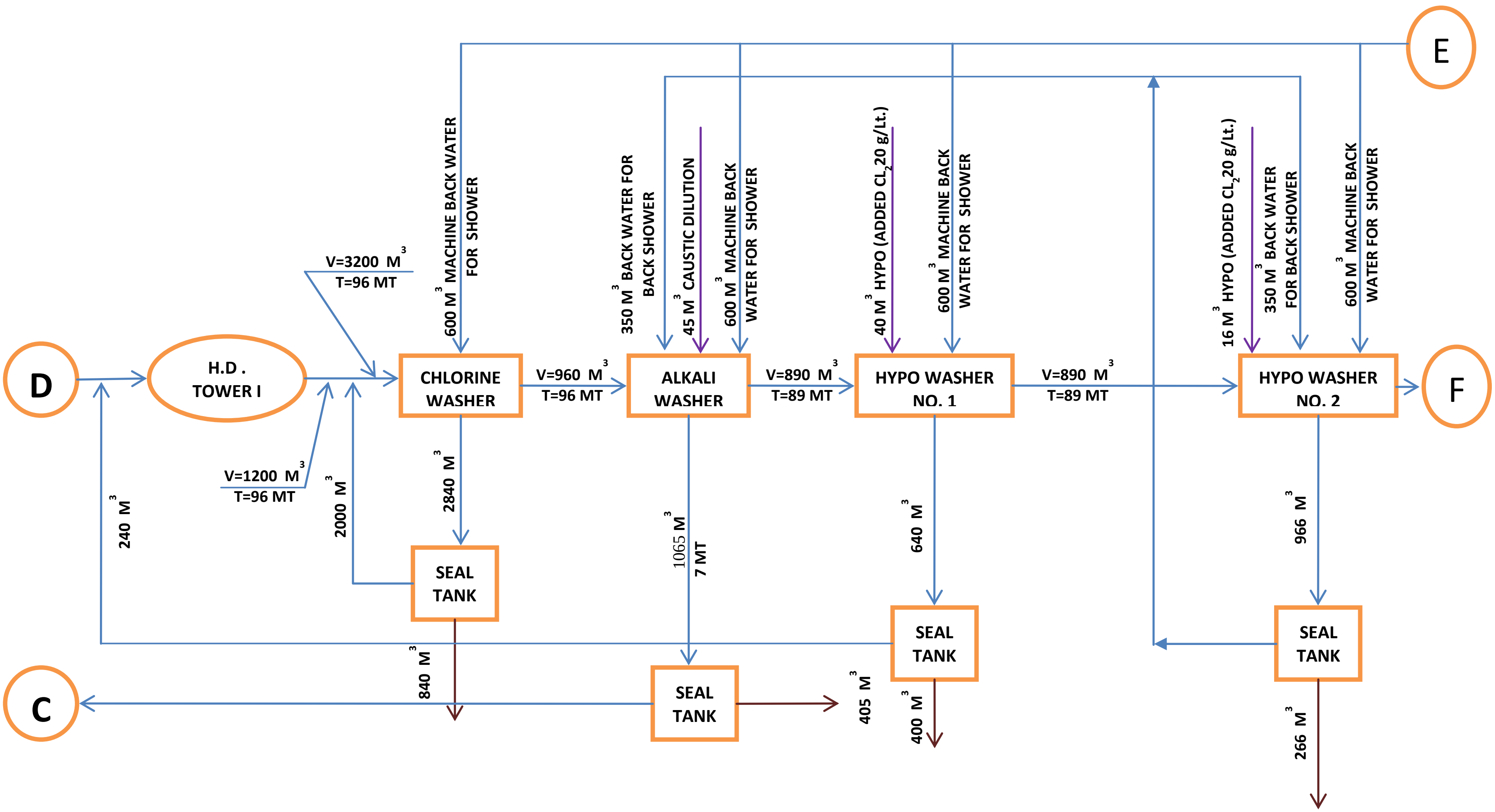


Figure 5.3 (c): Water/Mass Balance Diagram – (iii)

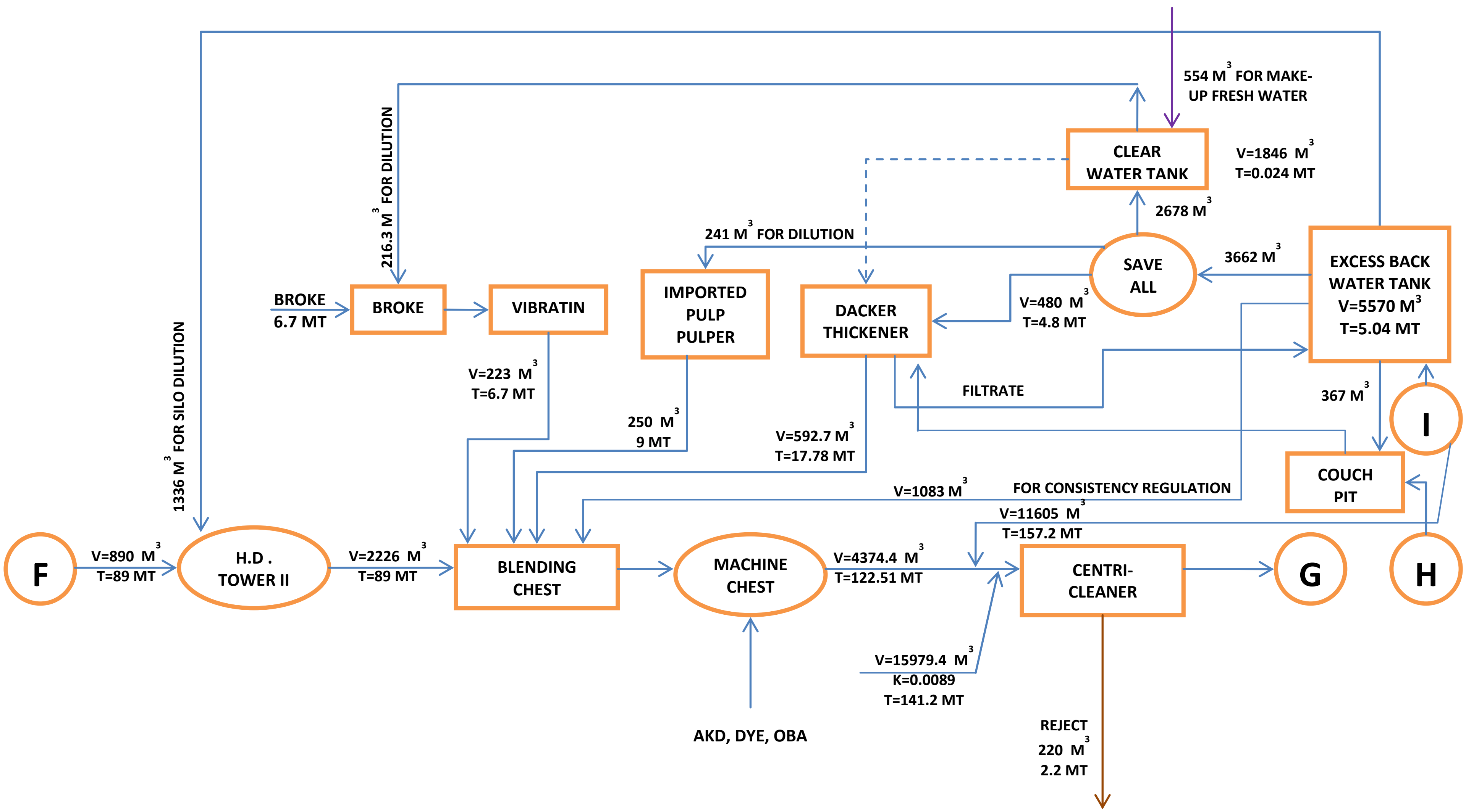


Figure 5.3 (d): Water/Mass Balance Diagram – (iv)

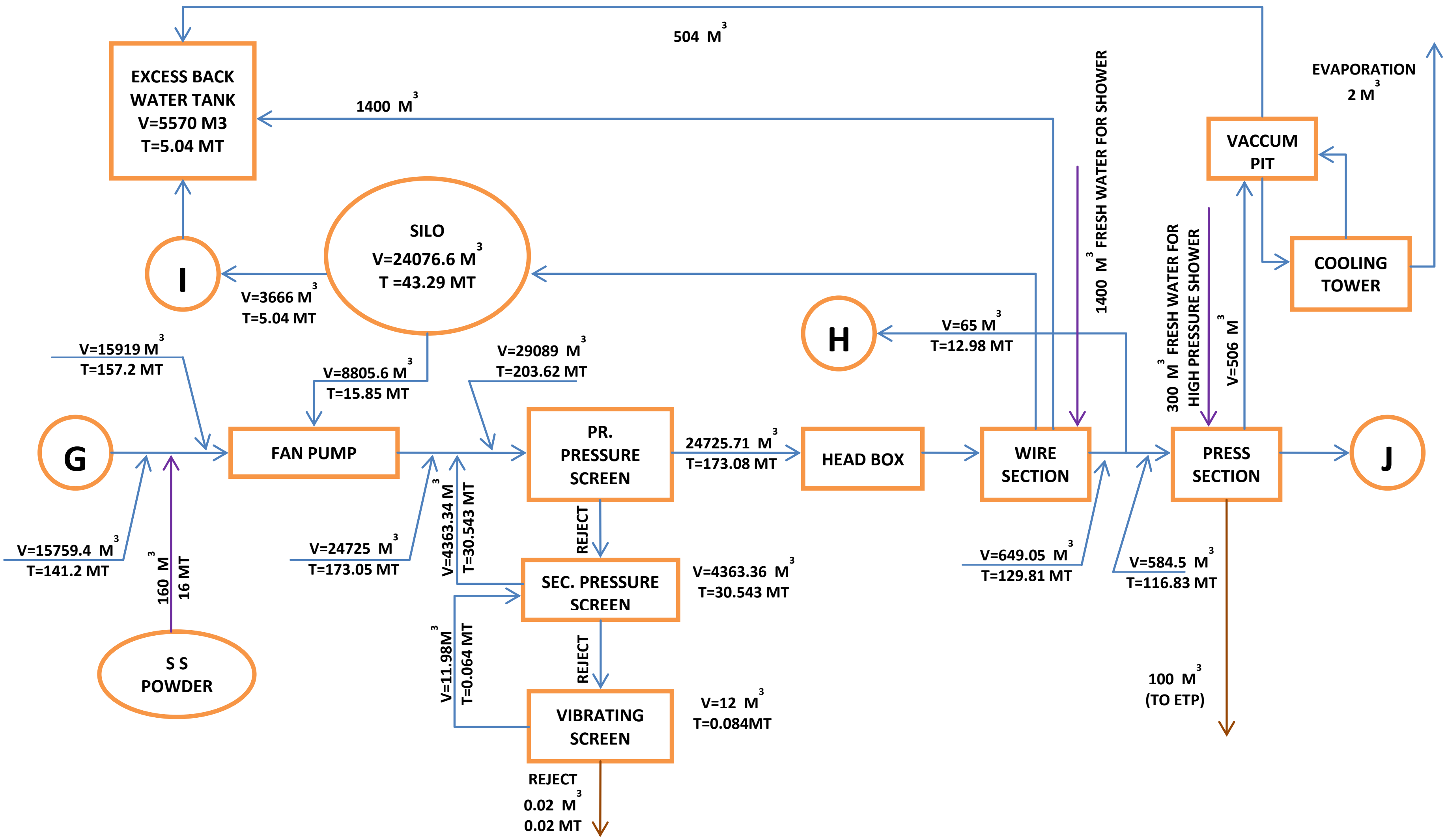


Figure 5.3 (e): Water/Mass Balance Diagram – (v)

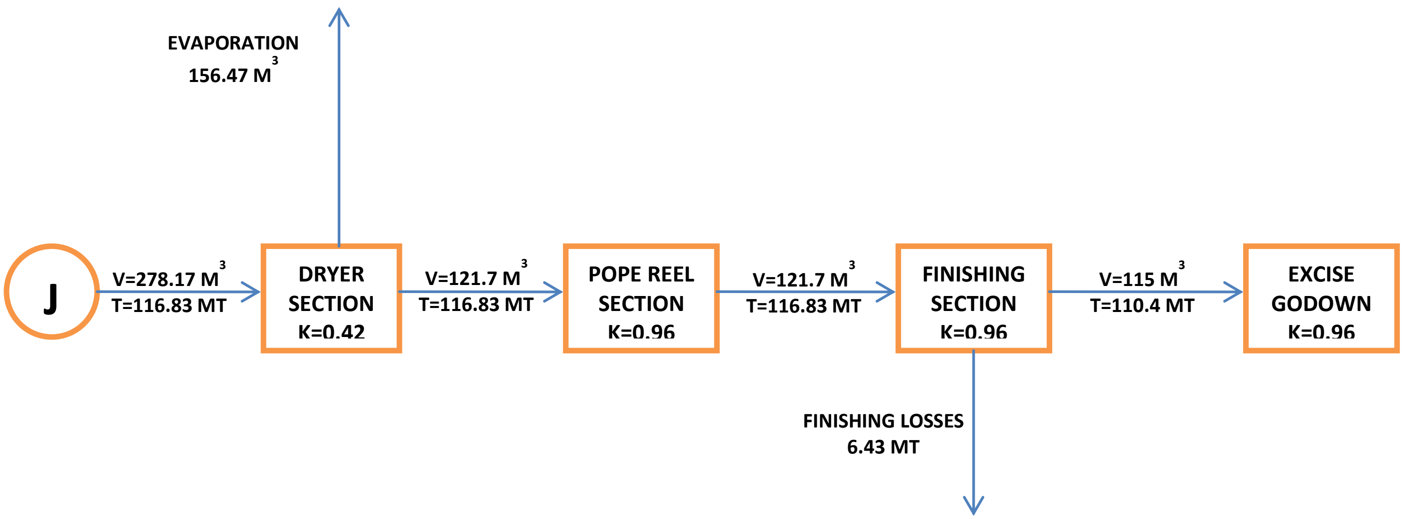


Figure 5.3 (f): Water/Mass Balance Diagram – (vi)

CHAPTER 6

TREATMENT OF PULP AND PAPER MILL WASTEWATERS

Many types of wastewater treatment systems are employed in pulp and paper industry. However, no single process will reduce all the major pollutants to regulatory standards and hence a combination of methods need to be used which include physical, physico-chemical, and biological systems. While most wastewater streams in the mill are controlled individually or pretreated before joining the common sewer, in most cases the combined wastewater receives the final treatment with exception of uncontaminated cooling water. The quality of the effluent desired and the mode of final disposal determine the type of the treatment to be adopted.

Type of methods adopted in a typical pulp and paper mill could be amongst the following mentioned processes/mechanisms:

1. **Physical Methods**
    a. Sedimentation and Floatation
2. **Physico-Chemical Methods**
    a. Chemical Flocculation
    b. Activated Carbon Adsorption
    c. Ultra Filtration
    d. Reverse Osmosis
    e. Chemical Oxidation
    f. Chemical Precipitation
3. **Biological Methods**
    a. Anaerobic Lagoons
    b. Stabilization Ponds
    c. Aerated Lagoons
    d. Activated Sludge Process
    e. Plastic Media Trickling Filters
    f. Rotating Biological Contactor (RBC)
    g. Anaerobic Contact Filter

Effluent Treatment Plants installed at Naini Papers Ltd. And Naini Tissues Ltd. works on the principle of ACTIVATED SLUDGE PROCESS which is the most successful method for treating pulp and paper mill wastewaters. Activated sludge operates at high oxygen levels. Nitrogen and phosphorus supplementation at 4.3 kg and 0.6 kg, respectively, would be the minimum for every 100 kg of BOD removal. Organic loading used vary from 0.2 to 0.5 kg BOD/kg MLSS/d with MLSS concentration ranging from 3,000 to 4,000 mg/l and aeration period between 4 to 9 hours. BOD removals of above 95 percent could be achieved in the system followed by secondary clarification. The conventional activated sludge process consists of an aeration tank, clarifier and a sludge recycle system and the design parameters for a Conventional Activated Sludge Process is given in *Table 6.1*. The process can be operated as a plug flow system, completely mixed system or somewhere between plug flow and complete mixing.

The normal drawbacks in the system are foaming in aeration tank, cost of nutrients and colour intensification.

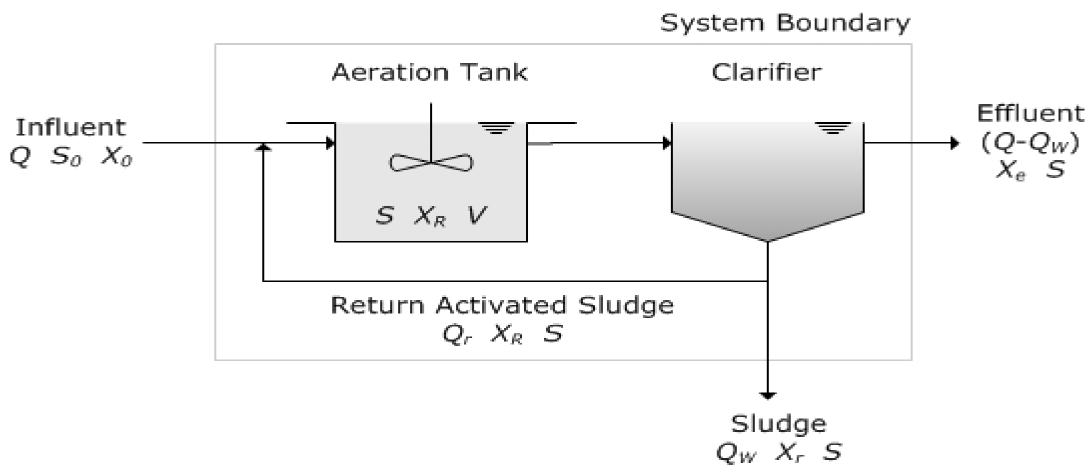


Figure 6.1: Activated Sludge Process Diagram

Table 6.1: Design parameters for Conventional Activated Sludge Process

Design Parameter	Range/Value
Retention Time, h	2 – 10
Organic Loading, kg BOD/kg MLSS/d	0.2 – 0.5
Sludge age, d	3 – 4
Sludge concentration, mg/l	3,000 - 4,000
Aeration tank depth, m	4
Clarifier surface Load, m/h	0.8 – 1.0

Problems may appear during the operation of activated sludge systems, including:

- High solids content in clarified effluent, which may be due to too high or too low solids retention time and to growth of filamentous micro-organisms.
- Rising sludge, occurring when sludge that normally settles rises back to the surface after having settled. In most cases, this is caused by the denitrification process, where nitrate present in the effluent is reduced to nitrogen gas, which then becomes trapped in the sludge causing this to float. This problem can be reduced by decreasing the flow from the aeration basin to the settling tank or reducing the sludge resident time in the settler, either by increasing the rate of recycle to the aeration basin, increasing the rate of sludge collection from the bottom, or increasing the sludge wasting rate from the system.
- Bulking sludge, that which settles too slowly and is not compactable, caused by the predominance of filamentous organisms. This problem can be due to several factors of which the most common are nutrient balance, wide fluctuations in organic load, oxygen limitation (too low levels), and an improper sludge recycle rate.
- Insufficient reduction of organic load, probably caused by a low solids retention time, insufficient amount of nutrients such as P or N (rare in fisheries wastewaters), short-circuiting in the settling tank, poor mixing in the reactor and insufficient aeration or presence of toxic substances.
- Odours, caused by anaerobic conditions in the settling tanks or insufficient aeration in the reactor.

6.1 STANDARDS FOR EFFLUENT AND EMISSIONS IN PULP AND PAPER MILL

In India, industry specific effluent standards are being evolved at the national level and are designated as ***"MINIMAL NATIONAL STANDARDS" (MINAS)***, which envisage treatment of all wastes to certain minimum standards regardless of the type of wastewater and location. MINAS are evolved considering the treatablility of the wastewaters and the various unit processes and operations that are available for treatment. The unit processes and operations are the building blocks and each has an associated cost factor. Any combination of unit processes and operations provides a stage of treatment and the performance of a treatment stage is expressed by the percentage removal of pollutants. The acceptability of the MINAS is very much linked to the techno-economic acceptability of the suggested stage of treatment which is possible by linking annualized cost or annual burden due to pollution control measures to the annual turnover of the industry. The stage of treatment whose annual burden remains within a critical percentage of annual turnover is accepted as minimal stage of treatment and the concomitant effluent standards is the MINAS.

The standards for pulp and paper mill effluent/emission have been evolved after looking into best practical technology, economics of the treatment alternatives, international standards and environmental acceptability.

The basic consideration that went into the development of the standards were, therefore, as follows:

- The characteristics of effluent from large pulp and paper/newsprint/rayon grade pulp with chemical recovery system;
- Achievability and techno-economic feasibility of various treatment alternatives; and
- Environmental acceptability.

Standards for liquid and gaseous emissions for large pulp and paper/newsprint/rayon grade pulp mills with chemical recovery are tabulated below:

Table 6.2: Standard limits for effluent and emissions

1. Liquid Emissions	
Parameters	**Limits**
pH	6.5-8.5
Suspended Solids	100 mg/l
BOD (5 days at 20 deg. C)	30 mg/l
COD	350 mg/l
FLOW:	
i) Paper mills	200 cum/tonne of product
ii) Newsprint/rayon grade pulp mills	175 cum/tonne of product
2. Gaseous Emissions from Recovery Boiler	
Parameter	**Limits**
Particulate matter	250 mg/Nm^3
H_2S	10 mg/Nm^3

Permissible limits for colour, which is contributed mainly from lignin, are not prescribed because no suitable economic technology is presently available.

6.2 EFFLUENT TREATMENT PLANT AT NAINI PAPERS LIMITED, KASHIPUR

Effluent Treatment Plant at Naini Papers Limited is of 10 MLD capacity and the process used for the treatment of mill wastewaters is Activated Sludge Process which is the most predominant process in Indian Pulp and Paper Industry. The wastewater from the unit is being segregated into two streams. One stream is drained water from the digester, known as ***black liquor***, and another stream is drained from pulp bleaching, paper machine and felt washings. The drained wastewater from unbleached pulp washing goes for soda-ash recovery plant and the other stream goes to ETP for further treatment.

The soda recovery plant has primarily two sections, i.e., evaporation of weak black liquor and incineration of thick black liquor. The weak black liquor is generated from brown stock washing system in pulp mill. Evaporation section is designed to concentrate weak black liquor from 8% to 15% total solids at the evaporation rate of 75 m^3/hr. The semi-concentrated black liquor is further concentrated from 25% to 45% dry solids in a direct contact venturу scrubber with the help of hot flue gases. The incineration of black liquor at 45% solids is completed in a fluidized bed reactor. The FBR is designed to match the capacity with evaporation plant. After incineration, sodium carbonate pallets are produced which is sold in the market.

Drained water from pulp bleaching, raw material washing, machine and felt washing goes to the effluent treatment plant for treatment. Considering all the features of the effluent, activated sludge process is being adopted for the treatment of the mixed effluent. From the equalization tank, the effluent is taken for color removal and pH adjustment, which is favorable for Bio-decomposition on oxidation and also removes oil & grease to two nos. of setting tank known as primary clarifier tank no. 1 & 2 through a flash mixing tank. This operation is being carried out with the addition of suitable chemicals.

Effluent from primary clarifier tank overflows to the reactor, where the bio-decomposition is being carried out by introducing the oxygen from the atmosphere with the help of surface aerators. This operation is carried out in a tank known as aeration tank. After decomposition of the effluent takes place, the coagulated liquor flows down to two nos. of secondary clarifiers, wherein suitable retention time is provided so that the sludge from the liquor settles down. Treated clear water is being disposed off into the drain.

From the secondary settling tank, part of the sludge is recycled to the aeration tank as per the need and the rest is constantly rejected to the specially designed sludge drying beds. Drained water from these beds is back to the equalization tank and sludge is scrapped periodically and lifted & used by cardboard manufacturers.

Table 6.3: Details of Equipment in existing E.T.P. (Naini Papers Limited)

S. No.	Items	Size (Mtr.)	Units
1	Equalization Tank	5.0 X 3.0 X 2.0 (D)	1
2	Primary Clarifier no. 1	20.0 Ǿ X 3.25 (D)	1
3	Primary Clarifier No. 2	19.0 Ǿ X 3.5 (D)	1
4	Aeration Tank	60.0 X 30.0 X 3.5 (D)	1
5	Secondary Clarifier No. 1	18.0 Ǿ X 3.25 (D)	1
6	Secondary Clarifier No. 2	17.0 Ǿ X 3.25 (D)	1
7	Sludge Filter	8‘Ǿ x 10’ face length	1
8	Aerator	30 HP	8

9	Feed Pumps	35 HP	2
10	Pump for Sludge Removal	Primary Clarifier 1 & 2 (15 HP)	1 each
		Secondary Clarifier 1 & 2 (15 HP)	1 each
11	Rake Arms	Primary Clarifier 1&2 (2 HP)	1 each
		Secondary Clarifier 1 & 2 (2 HP)	1 each

Table 6.4: Chemical Consumption in E.T.P. (Naini Papers Limited)

Sr. No.	Month	Chemical Consumption (Kgs)			
		Urea	DAP	Lime	Poly-electrolyte
1	April	2842	1917	11775	110
2	May	2894	1673	10646	105
3	June	2700	1574	10812	90
4	July	2979	346	0	0
5	August	3100	2015	9574	85
6	September	1755	1181	7274	61.5
7	October	3100	2015	9305.2	84.25
8	November	3483	1919	5842.8	57.5
9	December	3552	2478	25795	110.25
10	January	3220	2029	19241	84.25
11	February	2745	1799	27026	105.75
12	March	3100	2015	35509	122.5
	TOTAL	**35470**	**20961**	**172800**	**1016**

Table 6.5: Electricity Consumption in E.T.P. (Naini Papers Limited)

S. No.	Month	Electricity (KWH)
1	April	127326
2	May	109595
3	June	145016
4	July	34661
5	August	141803
6	September	132126
7	October	162420
8	November	155083
9	December	156942
10	January	154536
11	February	135503
12	March	144963
	Total	**1599974**

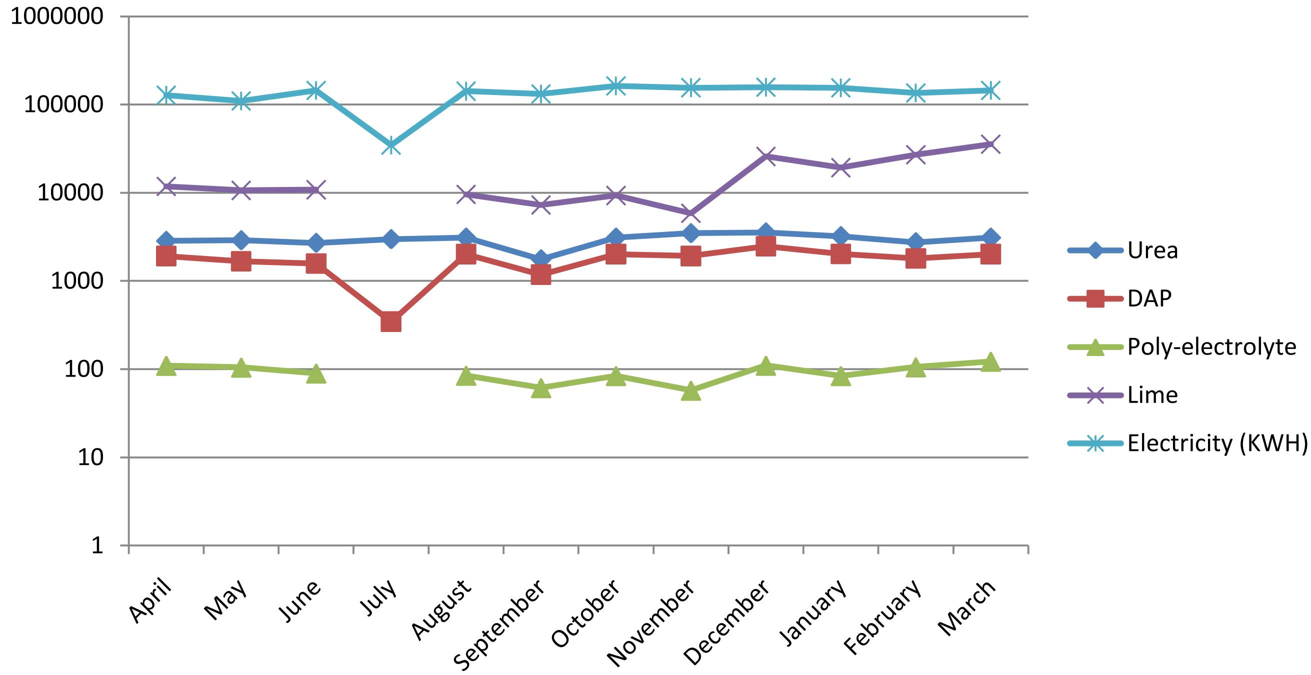


Figure 6.2: Chemical and Electricity Consumption in ETP (Naini Papers Limited)

6.3 EFFLUENT TREATMENT PLANT AT NAINI TISSUES LIMITED, KASHIPUR

The Effluent Treatment Plant installed at Naini Tissues Limited, Kashipur is of 10 MLD capacity for the treatment of wastewaters generated from the process of paper making from agricultural residues like wheat straw and bagasse. There are two streams from the plant through which the effluent from various section of the mill is taken to the ETP. The first stream consists of the effluent generated from wheat straw & bagasse washing, Paper Machine, and Stock Preparation Wastewater. Second stream consists of effluent generated from bleaching plant section of the mill and is taken to the foam yard in an underground line.

The two wastewater streams to the ETP constitutes a total volume of about 6000 m^3/day which is combined in a foam yard with dimensions as 19m X 10m X 2m. The combined effluent is then further passed through the bar screen and is allowed to enter into the equalization tank with a diameter of 5m and side water depth (SWD) of 2.5m. The equalization tank has a total volume of about 49m^3. From Equalization Tank, the effluent is then pumped into the overhead tank (size-4m X 2m X 1.5m) with the help of pumps (2 in nos. – one working and one standby) with a capacity of 450 m^3/hrs each having pump efficiency of about 80%.

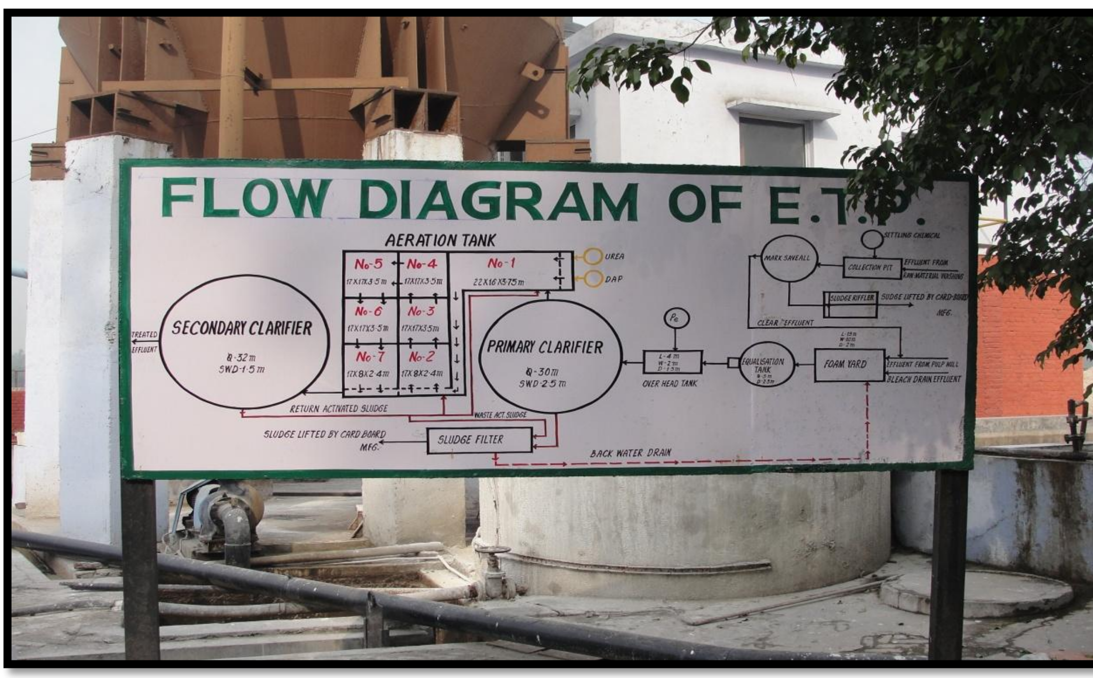


Figure 6.3: Flow Diagram of the Effluent Treatment Plant at Naini Tissues Limited

Figure 6.4: Foam Yard for collection of Bleaching Wastewater and Combined Wastewater from the manufacturing process

Figure 6.5: Equalization Tank in Effluent Treatment Plant (Naini Tissues Limited)

Figure 6.6: Primary Clarifier in ETP (Naini Tissues Limited)

The outlet of the overhead tank feeds the effluent into primary clarifier which has a diameter of about 30m with a side water depth of 2.5m. The total volume of the primary clarifier is 1768 m^3 with a retention time (detention period) of about 6 hours. In the primary clarifier, the suspended solids present in the effluent get settled at the bottom of primary clarifier which is then pumped to a sludge filter which further removes suspended solids. The filtered back water goes back into the inlet drain of the primary clarifier.

Overflow of primary clarifier is then passed through an aeration tank which consists of two chambers; first one is a service chamber and second one is main aeration tank. The effluent enters into first chamber of aeration tank (aeration tank no. 1 size -16m X 22m X 3.75m SWD, Volume=1320 m^3). Now, the overflow of this chamber feeds the effluent into the launder of main aeration tank of size - 42m X 34m X 3.5m SWD with a volume of about 4998 m^3. Hence, the total volume of aeration tank becomes 6318 m^3 and retention time is kept at 21.7 Hrs. There are a total of 9 nos. of floating and fixed type aerators in both the aeration tank (four nos. of aerators are provided with 10 H.P motor and 5 nos. of aerators are provided with 50 H.P motor), which is sufficient to provide a minimum DO level of 1.2 ppm and MLSS of 3200-3500 mg/l. Urea and DAP dosing is provided in the aeration tanks to fulfill the nutrient demand for an optimum growth of biomass and to maintain an appropriate F/M ratio. An optimum dissolved oxygen level along with biomass concentration is maintained to treat the effluent.

Figure 6.7: Aeration Tanks in Effluent Treatment Plant (Naini Tissues Limited)

Figure 6.8: Chemicals Used in ETP Process (Naini Tissues Limited)

The outlet of the aeration tank passes to secondary clarifier (Size – 32m Diameter with 1.5 SWD and Total Volume = 1200 m^3; Retention Time is to be kept at 4.1 Hours). In the secondary clarifier, the excess biomass settles down which is partly re-circulated into the aeration tank to maintain the biomass level and the overflow from the secondary clarifier goes to final discharge into the surrounding nallah just flowing along the boundary of the plant.

Figure 6.9: Secondary Clarifier in ETP (Naini Tissues Limited)

The sludge settled at the bottom of the primary clarifier is taken into a sludge tank. The excess secondary clarifier sludge remained after recirculation into aeration tank is also mixed with primary clarifier sludge and this sludge is then passed through vacuum operated sludge filter. The water drained during dewatering process of sludge is being taken back into the equalization tank. The dewatered sludge is sold to nearby cardboard manufacturers. The details of the equipments in ETP are given in *Table 6.6* while the chemical and electricity consumption are given in *Table 6.7* and *Table 6.8* respectively.

Figure 6.10: Sludge Thickener Facility and Sludge Storage Area

Table 6.6: Details of Equipment in existing E.T.P. (Naini Tissues Limited)

S. No.	Items	Size (Mtr.)	Units
1	Equalisation Tank	5.0 Ø x 2.5 (SWD)	1
2	Primary Clarifier	30.0 Ø X 2.5 (SWD)	1
3	Aeration Tank No. 1	16.0 X 22.0 X 4.1 (SWD)	1
4	Aeration Tank No. 2	42.0 X 34.0 X 3.5 (SWD)	1
5	Secondary Clarifier	32.0 Ø X 1.5 (SWD)	1
6	Sludge Filter System	2.5 Ø X 3.0 Face Length	1
7	Aerator	50 HP	5
8	Aerator	10 HP	4
9	Feed Pumps	30 HP	2
10	Pump for Sludge Removal	Primary Clarifier 20 HP	1
		Secondary Clarifier 20 HP	1
11	Rake Arms	Primary Clarifier 5 HP	1
		Secondary Clarifier 2 HP	1

All dimesions given above of equalization tank, primary clarifier, aeration tank, secondary clarifier & sludge filter system are in meters.

Figure 6.11: EFFLUENT TREATMENT PLANT FLOW SHEET (NTL)

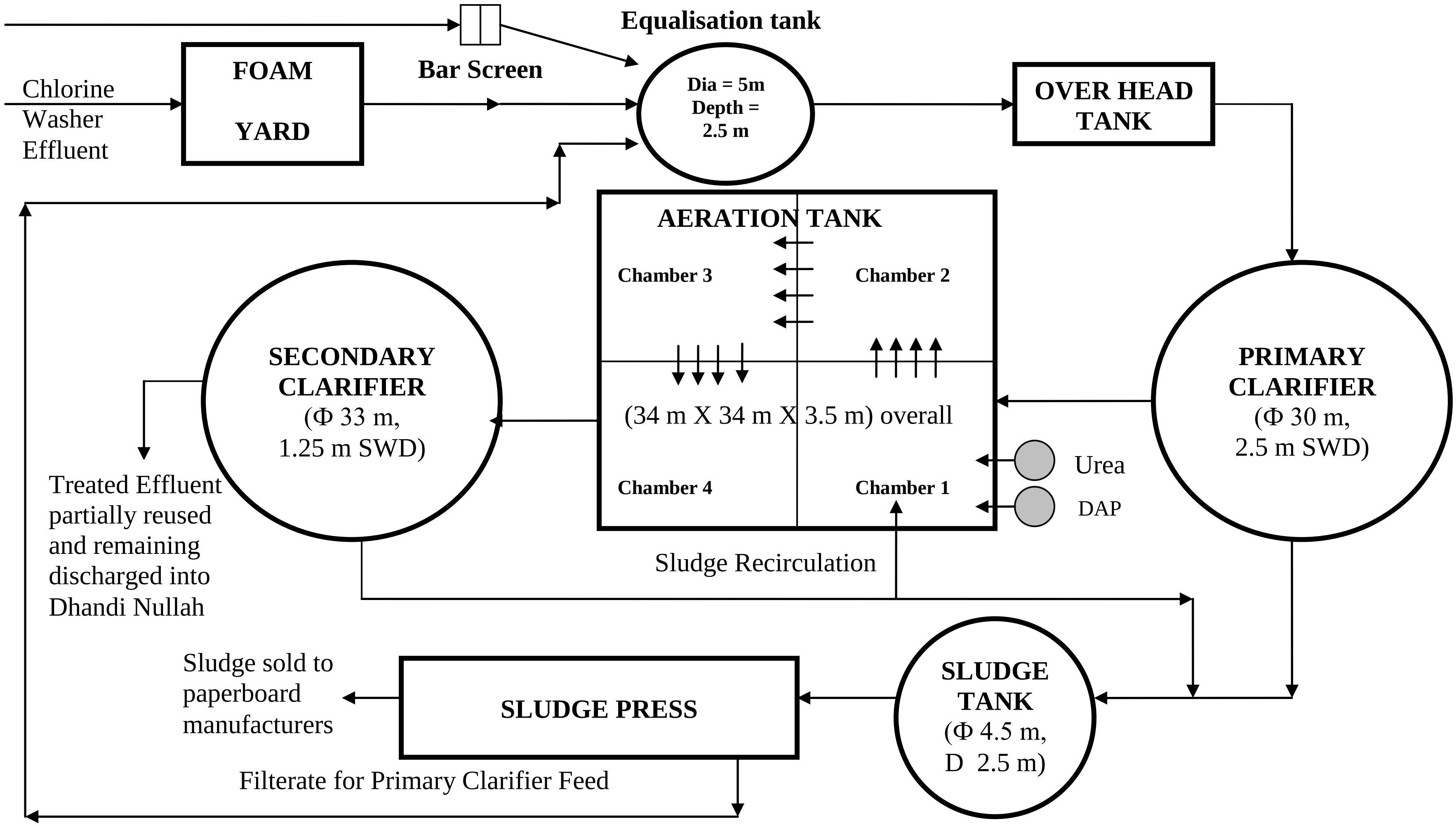


Table 6.7: Chemical Consumption in E.T.P. (Naini Tissues Limited)

Sr. No.	Month	Chemicals Consumption (Kgs)			
		Urea	DAP	Polyelectrolyte	Lime
1	April	4250	2833	166	17100
2	May	4650	3784	185	18400
3	June	4475	2983	144	17850
4	July	4350	2899	172	17400
5	August	4550	3033	182	18200
6	September	4350	2865	173	17100
7	October	4600	3066	183	481195
8	November	3797	4214	180	17800
9	December	4297	3299	170.45	18400
10	January	5475	3916	131	13129
11	February	4200	2800	168	17100
12	March	5300	3520	186	20670
	Total	**54294**	**39212**	**2040.45**	**674344**

Table 6.8: Electricity Consumption in E.T.P. (Naini Tissues Limited)

S. No.	Month	Electricity (KWH)
1	April	144933
2	May	161674
3	June	152684
4	July	152660
5	August	127757
6	September	127851
7	October	154723
8	November	163563
9	December	170250
10	January	174602
11	February	161837
12	March	180277
	TOTAL	**1872811**

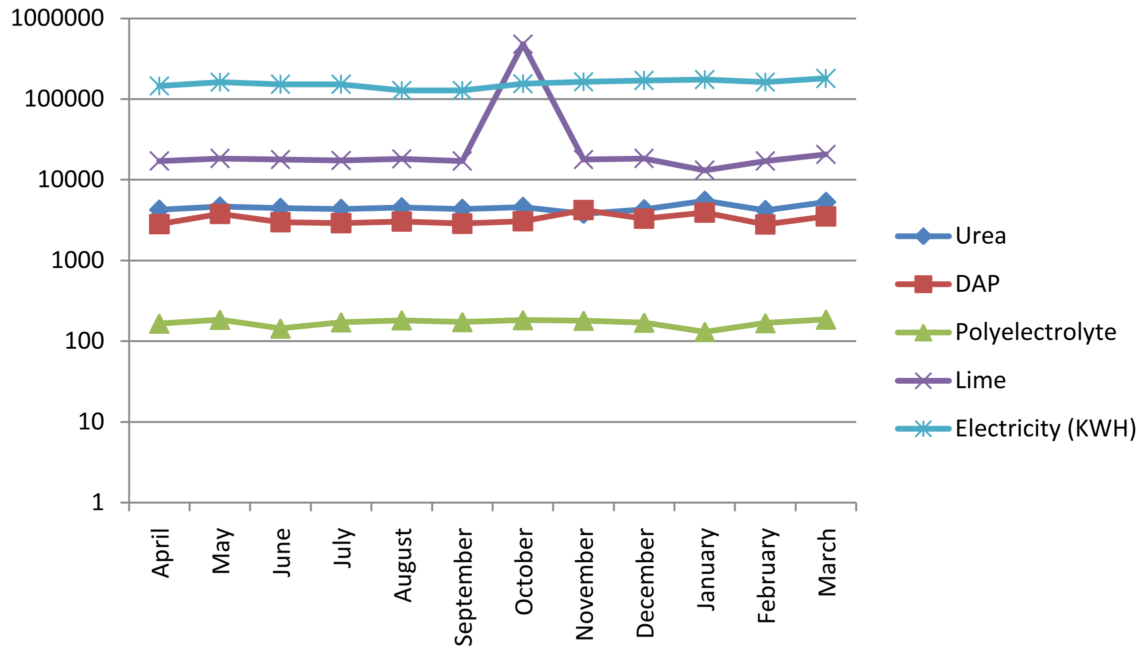


Figure 6.12: Chemical and Electricity Consumption in ETP (Naini Tissues Limited)

CHAPTER 7

RESULTS AND DISCUSSION

7.1 CHEMICAL CHARACTERIZATION OF DRAINS TO ETP

Chemical characterization of the drains was done so as to get an overview of what type of wastewater is being submitted to drains and then finally to Effluent Treatment Plant at Naini Tissues Limited, Kashipur. For carrying out the same, some locations were identified and in this regard, samples were collected on 15/01/2011. The parameters studied were pH, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). Also, the chemical characterization of chemical recovery drain to the ETP was done as shown in *Table 7.2*. Analysis of the samples collected was made in accordance of Standard Methods for Examination of Water and Wastewater. The results of the same are given in *Table 7.1*.

Table 7.1: Chemical Characterization of Drains to ETP (Naini Tissues Limited) as on 15/01/2011

Location	Parameters			
	pH	TSS (mg/l)	BOD (3-day, 27^{o}C) (mg/l)	COD (mg/l)
Unbleached Waste Water	7.1	930	1157	3305
Paper Machine Reject (Centri-Cleaner Reject)	7.8	322	403	2326
Clear Save-All	7.2	310	43	163
Alkali Washer Seal Pit	8.5	180	475	1380
Hypo – I Seal Pit	7.4	170	220	880
Hypo – II Seal Pit	7.7	220	13	1183
Wet Washing Riffler	7.15	210	497	1346
Wet Washing (Pulping)	5.6	2390	1407	7100

It has been observed that the pulping operation i.e. Wet Washing, generates wastewater which has high TSS (2390 mg/l) in form of unused fiber materials, high BOD (1407 mg/l) and very high COD (7100 mg/l) as per *Table 7.1*. From *Table 7.1*, it can be inferred that Wet Washing (Pulping), Wet Washing Riffler (BOD – 497 mg/l and COD – 1346 mg/l) and Unbleached wastewater (TSS – 930 mg/l, BOD – 1157 mg/l and COD – 3305 mg/l) contributes to the pollution load to the ETP as other drains have moderate values of BOD and Total Suspended Solids. The waste water from Clear Save-All process is generally being reused in washing operation itself before it has to be submitted finally to ETP along with other wastewaters. Also, some of the wastewater from Hypo –II Seal Pit (TSS – 220 mg/l and BOD – 13 mg/l) is being reused in the Hypo Washer – II and Alkali Washer itself and rest is being submitted to the ETP drain.

Table 7.2: Chemical Characterization of Chemical Recovery Drain to ETP (Naini Tissues Limited) as on 18/01/2011

Location	Parameters				
	pH	**TSS (mg/l)**	**BOD (3-day, 27^{o}C) (mg/l)**	**COD (mg/l)**	**Color (Pt-Co Units)**
Chemical Recovery Drain	9.5	110	425	754	2925

The recovery drain from the Chemical Recovery Plant is also being submitted into the ETP drain as a separate drain which gets mixed into the combined wastewater drain just before the Foaming Tank. However, the practice is not done regularly and is only done when there is some maintenance issues with the recovery plant or if washing operation is being carried out. The wastewater was found to be light black in colour as it contains mostly the oil which is used in the evaporators in Chemical Recovery Plant and diluted black liquor. This drain generally comprises of wastewater generated from washing of the Chemical Recovery Plant Evaporators and hence doesn't has a high TSS concentration (110 mg/l). The wastewater has a high BOD (425 mg/l), COD (754 mg/l) and Colour (2925 Pt-Co Units) as per *Table 7.2* adding up to the combined wastewater drain coming from the manufacturing process. This drain is only submitted to the ETP whenever there is a washing/cleaning operation of the Chemical Recovery Plant as per the requirement of the same.

7.2 PERFORMANCE EVALUATION OF ETPS

Performance evaluation of an Effluent Treatment Plant (ETP) is carried out in order to assess the performance efficiency of the ETP units. It provides information about the removal efficiency of various important parameters such as pH, BOD, COD and Colour at different points in an ETP. By evaluating the performance of the ETP, one can assure of its working efficiency and also to investigate that whether the ETP is running with full optimization with no or little maintenance required.

A comprehensive program to evaluate performance evaluation of ETPs at Naini Papers Limited and Naini Tissues Limited was undertaken in January 2011, prior to which the wastewater generation and management of the whole mill was studied. Also, the samples were collected on daily basis and analysis was carried out as per the Standard Methods for Examination of Water and Wastewater, APHA.

The points of sampling in case of both the ETPs taken into consideration were Combined Wastewater Drain, Primary Inlet, Primary Outlet and Secondary Outlet while assessing the performance evaluate of the ETPs. The results of the parameters at the aforementioned sampling points are indicated in *Table 7.3 to Table 7.8*. Effluent Treatment Plant installed at Naini Tissues Limited was first taken up for sampling and analysis. In this regard, samples were taken daily from 17/01/2011 to 19/01/2011 at the aforementioned points of sampling. The results of the analysis for the same are as per *Table 7.3, 7.4* and *7.5* for 3-consecutive days of sampling as shown below:

Table 7.3: Analysis of ETP inlet/outlet points (Naini Tissues Limited) as on 17/01/11

Parameters	TSS (mg/l)	pH	BOD (3 day - 27 deg C) (mg/l)	COD (mg/l)	Color (Pt Co)
Combined Wastewater	1040	6.37	593	3412	8575
Primary Inlet	1410	8.05	503	2420	7225
Primary Outlet	190	5.86	437	1428	5775
Secondary Outlet	90	7.33	15.5	367	1615

Table 7.4: Analysis of ETP inlet/outlet points (Naini Tissues Limited) as on 18/01/11

Parameters	TSS (mg/l)	pH	BOD (3 day - 27 deg C) (mg/l)	COD (mg/l)	Color (Pt Co)
Combined Wastewater	2730	6.9	1035	3809	6500
Primary Inlet	4190	9.3	575	2976	6175
Primary Outlet	280	6.5	502	1468	3900
Secondary Outlet	100	7.5	18.9	377	1695

Table 7.5: Analysis of ETP inlet/outlet points (Naini Tissues Limited) as on 19/01/11

Parameters	TSS (mg/l)	pH	BOD (3 day - 27 deg C) (mg/l)	COD (mg/l)	Color (Pt Co)
Combined Wastewater	4730	5.8	1412	3889	8725
Primary Inlet	1670	5.6	1052	3532	7225
Primary Outlet	500	5.86	676	1587	4850
Secondary Outlet	230	7.4	18.6	407	1630

Similarly, Effluent Treatment Plant installed at Naini Papers Limited was considered from 20/01/2011 to 22/01/2011 for the sampling and analysis purpose. The results of the analysis for the same are as per *Table 7.6, Table 7.7* and *Table 7.8* for 3 consecutive days of sampling. The high values of BOD and COD of raw effluents could be attributed to the presence of chemical substances i.e. resin, alum, caustic soda, poly-aluminium chloride and the breakdown of various organic compounds in the raw materials used for paper production.

Table 7.6: Analysis of ETP inlet/outlet points (Naini Papers Limited) as on 20/01/11

Parameters	TSS (mg/l)	pH	BOD (3 day - 27 deg C), (mg/l)	COD (mg/l)	Color (Pt Co)
Combined Wastewater	230	7.2	673	1131	3950
Primary Inlet	200	7.23	453	1091	4925
Primary Outlet	180	6.75	257	949	3575
Secondary Outlet	90	7.47	14	242	845

Table 7.7: Analysis of ETP inlet/outlet points (Naini Papers Limited) as on 21/01/11

Parameters	TSS (mg/l)	pH	BOD (3 day - 27 deg C), (mg/l)	COD (mg/l)	Color (Pt Co)
Combined Wastewater	200	7.85	537	833.3	2075
Primary Inlet	180	7.62	357	754	2800
Primary Outlet	160	6.75	228	575.4	2225
Secondary Outlet	70	7.47	15.3	238	815

Table 7.8: Analysis of ETP inlet/outlet points (Naini Papers Limited) as on 22/01/11

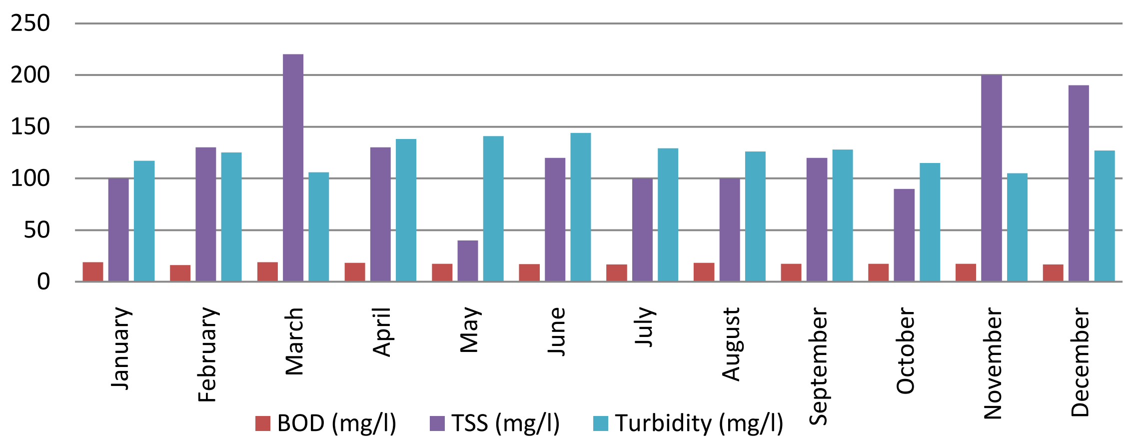
Parameters	TSS (mg/l)	pH	BOD (3 day - 27 deg C), (mg/l)	COD (mg/l)	Color (Pt Co)
Combined Wastewater	210	7.75	453.3	873	2350
Primary Inlet	140	7.6	383.3	714	3100
Primary Outlet	120	7.1	176.7	615	2300
Secondary Outlet	80	7.7	15.9	258	825

Removal efficiency of the parameters tested for the ETPs at Naini Tissues Limited and Naini Papers Limited are shown as per *Figure 7.2* and *Figure 7.3* respectively. It can be seen from *Figure 7.2* that the average removal efficiencies for TSS, BOD, COD and Colour are 94%, 98%, 89% and 79% respectively. Though COD average value comes around 384 which is higher in terms of Effluent Standards to be maintained. It can be attributed to the fact that the ETP is working at par with standards laid by UEPPCB but still the values of COD are above the standards and hence needs to be brought down below 350 mg/l.

However, the effluent treatment plant at Naini Papers Limited has average removal efficiencies of 63%, 97%, 74% and 68% for TSS, BOD, COD and Colour respectively. The plant is running at full efficiency with all the final effluent parameters under the prescribed limits of effluent standards set by UEPPCB. However, the efficiencies of the removal as compared to ETP at Naini Tissues Limited are somewhat low in TSS and COD removal. The difference in the values of both the ETPs are acknowledged by the fact that Naini Papers Limited has an Oxygen Delignification Plant which actually supports the ETP process well and hence reduction in parameters are enhanced as compared to ETP in Naini Tissues Limited which still lacks installation of an Oxygen Delignification Plant.

Table 7.9: Previous Year (2009-2010) Monthly Final Effluent Parameters

Month	pH	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	Turbidity (mg/l)	Color (Pt-Co units)
January	7.6	19.05	384	100	117	1915
February	7.7	16.3	472	130	125	2610
March	8.0	19.00	369	220	106	1935
April	7.9	18.30	401	130	138	2525
May	7.9	17.50	459	40	141	2650
June	7.8	17.00	481	120	144	2580
July	7.8	16.75	466	100	129	2385
August	7.8	18.30	480	100	126	2170
September	7.8	17.50	473	120	128	2395
October	7.8	17.40	458	90	115	2175
November	7.5	17.30	428	200	105	1925
December	7.6	16.70	443	190	127	2305



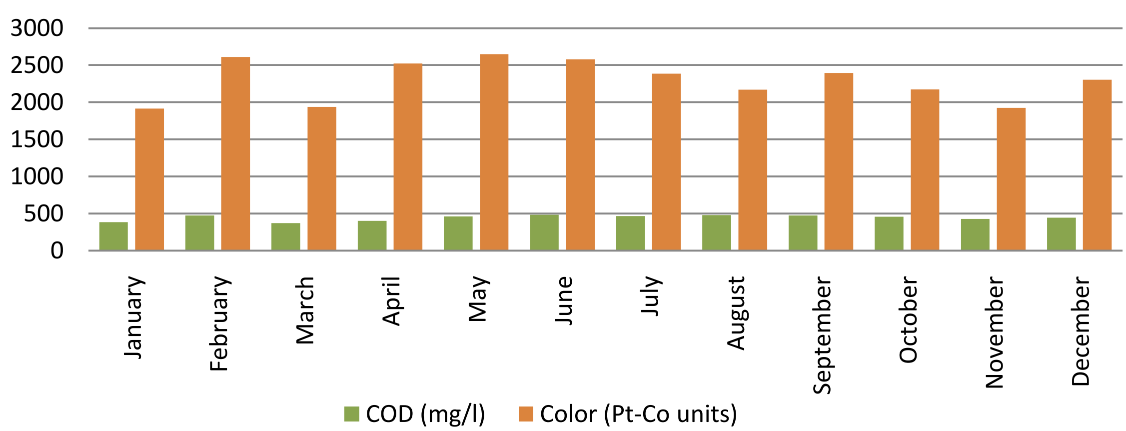


Figure 7.1: Previous Year (2009-2010) Monthly Final Effluent Parameters

To assess the performance of the ETP at Naini Tissues Limited, the results from the previous year final effluent parameters were taken from the plant management and the same are reported in *Table 7.9*. Monthly Values of parameters are shown graphically in *Figure 7.1*. The data was taken considering one day of the every month in a year. The average values for the year (2009-2010) in ETP at Naini Tissues Limited are as follows:

1.	**pH**	7.77
2.	**BOD (mg/l)**	17.59
3.	**COD (mg/l)**	442.83
4.	**TSS (mg/l)**	128.33
5.	**Colour (Pt-Co units)**	2297.50

Comparing these to the 3-days average in the month of January as per *Table 7.3 to Table 7.5* i.e. pH (7.41), BOD (17.67 mg/l), COD (383.67 mg/l), TSS (140 mg/l) and Colour (1646.67 Pt-Co units), it can be inferred that the values are in accordance to the yearly average with slight deviations in case of COD and Colour. However, in case of previous year January values with this year's January values, the parameters are in accordance though the value of COD exceeds in both the cases, above the prescribed standards for final effluent.

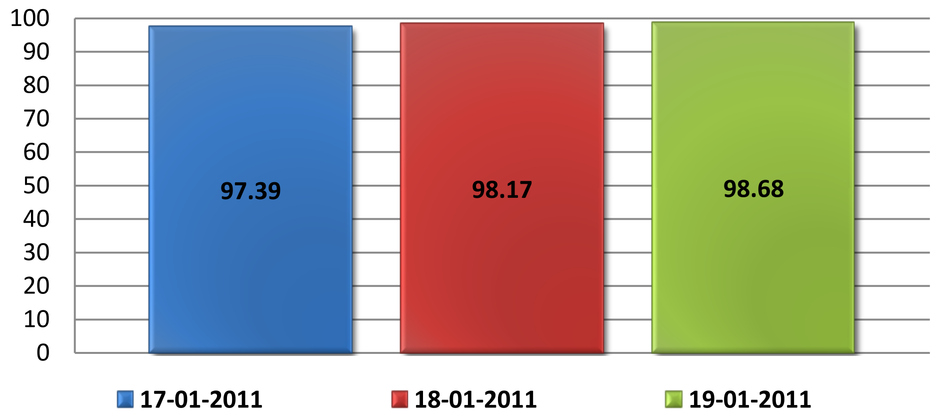


Figure 7.2: Removal Efficiency (%) of Biochemical Oxygen Demand at Naini Tissues Limited

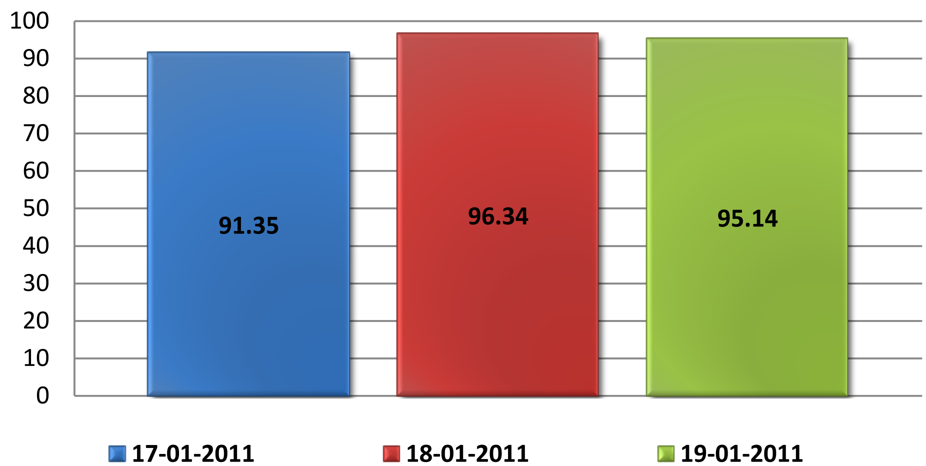


Figure 7.3: Removal Efficiency (%) of Total Suspended Solids (TSS) at Naini Tissues Limited

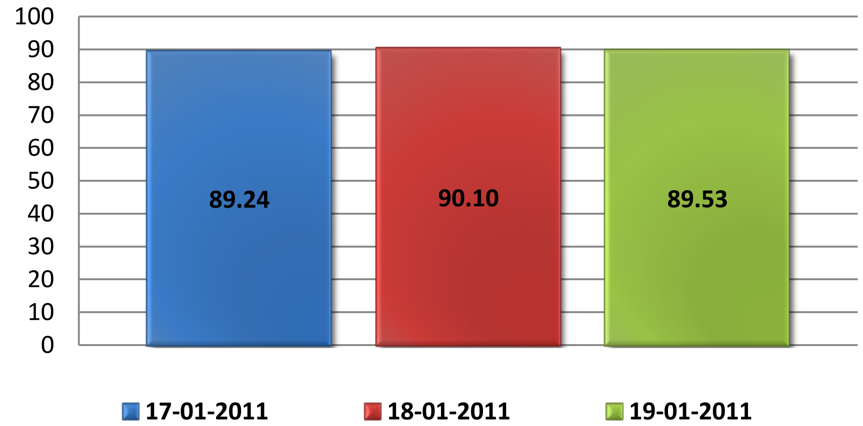


Figure 7.4: Removal Efficiency (%) of Chemical Oxygen Demand (COD) at Naini Tissues Limited

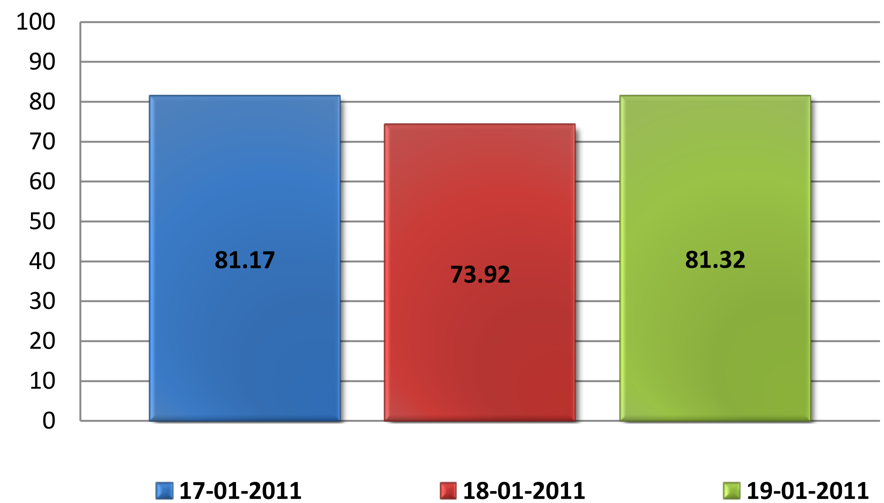


Figure 7.5: Removal Efficiency (%) of Colour at Naini Tissues Limited

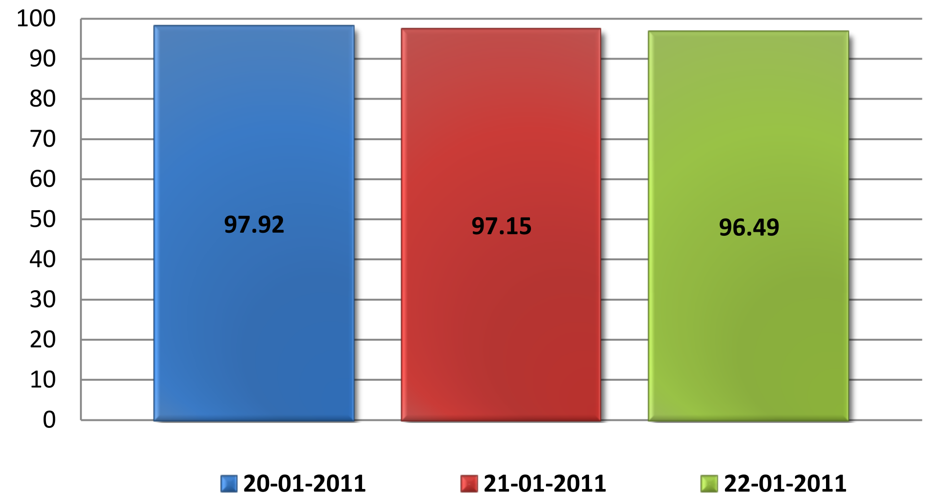


Figure 7.6: Removal Efficiency (%) of Biochemical Oxygen Demand (BOD) at Naini Papers Limited

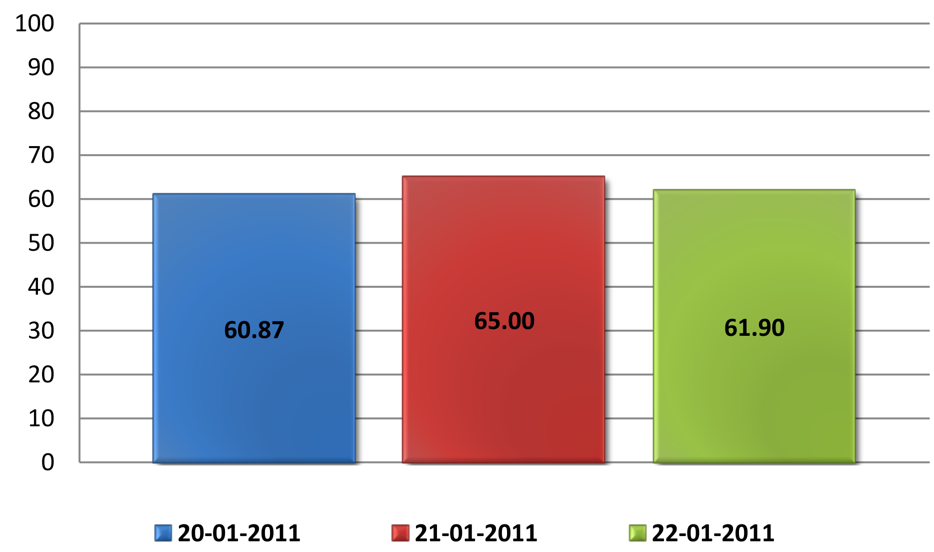


Figure 7.7: Removal Efficiency (%) of Total Suspended Solids (TSS) at Naini Papers Limited

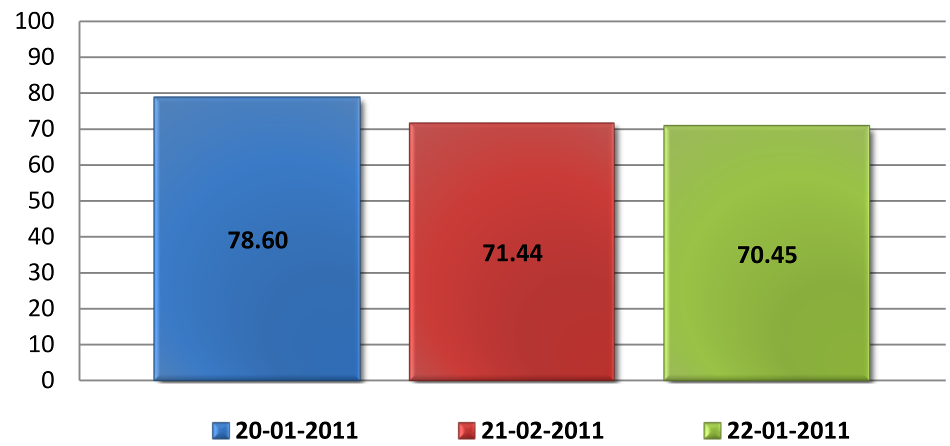


Figure 7.8: Removal Efficiency (%) of Chemical Oxygen Demand (COD) at Naini Tissues Limited

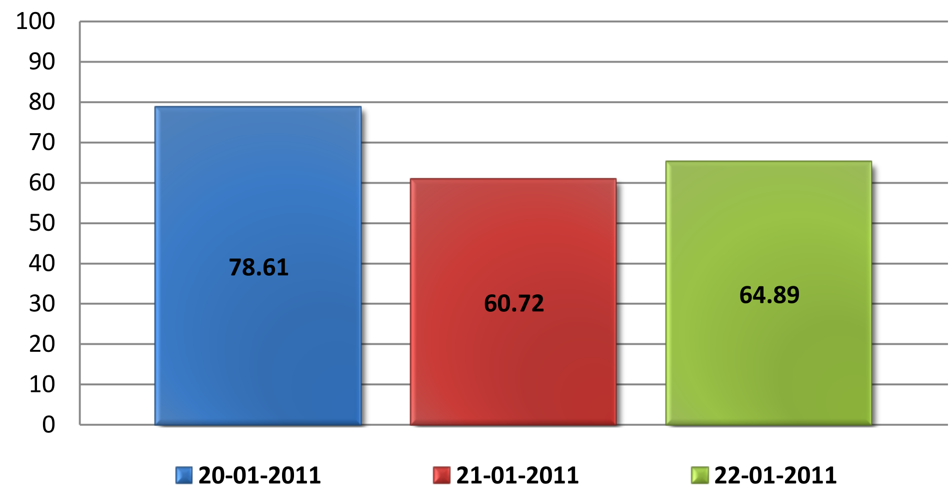


Figure 7.9: Removal Efficiency (%) of Colour at Naini Papers Limited

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Based on the study following conclusions are made:

1. Naini Tissues Limited and Naini Papers Limited has an ETP installed of 10 MLD capacity that is working at par with the effluent standards formed by Uttarakhand Environmental Protection and Pollution Control Board (UEPPCB) for Pulp and Paper Mills though Chemical Oxygen Demand (COD) in case of ETP installed in Naini Tissues Limited, Kashipur is still an area of concern as COD should be less than 350 mg/l. As per the analysis of ETP of Naini Tissues Limited and Naini Papers Limited, it can be inferred that the plants are running at par to meet the effluent standards with some exceptions. Naini Group of Industries is following all the Environmental Norms under Water and Air Act as directed by Central Pollution Control Board and is *ISO 9001:2008, ISO 14001:2004 and OHSAS 18001:2007* certified company certified by *Det Norske Veritas* (DNV).
2. Oxygen Delignification Technology is a state of the art technology which has been installed in Naini Papers Limited, which considerably reduced the chlorine consumption during the bleaching process and hence the formation of organohalide compounds (AOX) are also reduced. Also, by using oxygen delignification before the bleaching process, Kappa Number gets reduced and hence the strength and quality of the paper produced also gets enhanced. A comparative reduction between ETPs of Naini Group of Industries, of about 20% in TSS, 18% in BOD, 40% in COD and 48% in Colour was observed if Oxygen Delignification is being employed before sending the unbleached pulp to the Bleaching Section.
3. The reduction in BOD and COD levels are due to the biological treatment and removal of biodegradable organic fraction and its derivatives from the effluent. All scum/solid materials collected at the screens in the combined wastewater streams should be regularly removed to avoid the choking of the effluent flow as they are open drains which might add to suspended solids concentration which must be avoided.
4. Average removal efficiencies of 63%, 97%, 74% and 68% for TSS, BOD, COD and Colour respectively for Naini Papers Limited was observed while the average removal efficiencies for TSS, BOD, COD and Colour are 94%, 98%, 89% and 79% respectively at Naini Tissues Limited was observed.

5. Regular monitoring of the pH, Total Suspended Solids, BOD, COD, and nutrients is being carried out at Naini Group of Industries for regulating the addition of chemicals to wastewater and continued improvement in the efficiency of the effluent treatment plant.
6. Reduction of effluent volume and treatment requirements is being practiced by recovering pulping chemicals by concentrating black liquor and burning the concentrate in a recovery furnace; recovering cooking chemicals by recausticizing the smelt from the recovery furnace; and using high-efficiency washing and bleaching equipment.

8.2 RECOMMENDATIONS

Following recommendations are made based on the study:

1. An oxygen delignification plant in Naini Tissues Limited should be commenced so as to reduce the lignin content of the pulp. Commissioning of Oxygen Delignification Technology in Naini Tissues Limited at the earliest would ensure the improvement in quality of the final effluent to be discharged into the Nallah adjacent to Naini Tissues Limited.
2. Modifications in the effluent treatment plant can produce much more effective results if certain methods are adopted such as Tertiary Treatment after the Secondary Clarifier, adopting MBBR with diffused aeration etc. for which cost analysis needs to be done before adopting the same in the existing plant as these methods might or might not prove to be cost effective as far as Pulp and Paper Industry is concerned.
3. Effluent Treatment Plants at Naini Tissues Limited and Naini Papers Limited are presently running on Activated Sludge Process with aeration being provided with the help of Submerged Type Surface Aerators which consumes lot of electricity. However, these can be replaced by Diffused Aerators which are capable of proper mixing of air in the Aeration Tank as the diffusers provides homogenization of air from the bottom of the tank and hence the activity of micro-organisms increases thereby making the Activated Sludge Process more effective in terms of reduction of parameters. Also, diffused aerators consume considerably less electricity and hence provide cost benefit to the company. However, maintenance of the Diffused Aerators is a tedious work and requires complete removal of the whole assembly in terms of cleaning the whole system. Experience workmanship is also required in terms of maintaining the same. Hence, the use of Diffused Aeration should only be adopted if the process is cost effective and has a small payback period to make its use effective in a pulp and paper industry. In case of Pulp and Paper industry, it is

however difficult to maintain the efficiency of the Diffused Aeration system because of the clogging of the pores due to fibers in the laterals of the system and closing down of the operation of ETP while maintenance periods is a problem.

4. Minimization of unplanned or non-routine discharges of wastewater and black liquor, caused by equipment failures, human error, and faulty maintenance procedures, by training operators, establishing good operating practices, and providing sumps and other facilities to recover liquor losses from the process areas.

5. Reduce bleaching requirements by process design and operation such as before bleaching, reduce the lignin content in the pulp by extended cooking and by oxygen delignification under elevated pressure; optimize pulp washing prior to bleaching; use TCF or at a minimum, ECF bleaching systems; use of oxygen, ozone, peroxides (hydrogen peroxide), per-acetic acid, or enzymes (cellulose-free xylanase) as substitutes for chlorine-based bleaching chemicals; recover and incinerate maximum material removed from pulp bleaching; where chlorine bleaching is used, reduce the chlorine charge on the lignin by controlling pH and by splitting the addition of chlorine.

6. At present, there are no cost effective methods for reduction of colour in pulp and paper industry which arises due to lignin and its derivatives, as per State Pollution Control Boards. However, research is being carried out for finding a solution in colour removal so as to maintain the aesthetic value of the final effluent being submitted to a drain which subsequently might end up in a river. Colour reduction at the source is the most practical method while there have been several promising methods, though a combination of these techniques would prove beneficial in terms of developing a cost effective solution for colour removal. Some of the end-of-pipe methods that can be used for colour removal are based on Physical Adsorption, Chemical-Oxidative Decolourisation, Biological-Fungal/Enzymatic decolourisation, Electrochemical Decolourisation, Chemical Coagulation and Precipitation, Membrane Process, Photo-oxidation and Ion Exchange processes.

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