Waste Management in Pulp & Paper Industry : A System Perspective

Mall I.D.

ABSTRACT

The present paper highlights major environmental issues, waste generation and its management, cleaner production technologies and role of waste audit and waste management information system in the reducing the wastage and improving the productivity.

INTRODUCTION

With the globalization of Indian economy and need for cleaner environment, the Indian paper industry is in pursuit of its modernization and upgradation to improve not only quality and productivity but also to go for cleaner production with reduced losses and improved environmental managment to make competitive in the international market. The future pulp & paper mill will be expected to be virtually effluent free with maximum utilization of resources in the form of material, energy, capital and manpower. Waste management information system will be an important tools for increasing the productivity of the mills, reducing the losses and helping the management & operating personnel to control the wastage and cost of raw material and utilities on day to day basis by comparing the actual consumption of raw materials, discharges and emissions with that of standard norms. The process of cleaner production starts with the innovative thinking towards resource conservation, quality of the products and low waste generation with optimum attention towards maintaining the cleaner production.

With merely 17 units in 1950 with production of 0.16 million tonnes paper, presently India have about 406 mills with a total installed capacity of around 6.12 million tonnes using mix raw materials bamboo-wood (37%), agricultural residues (31%) and waste paper (32%) with capacity utilization around 67% [1].

Although many of the environmental issues in the developed countries have been resolved but situation in Indian paper indstury is entirely different due to low capacity plants with poor infrastructure facilities and use of agricultural residues and still lot of things have to be done in Indian paper industry to resolve these issues. As the pulping & paper making industry is capital intensive, pollution prevention in the industry continue to rely on recycle, source reduction and process modification.

The present paper highlights the profile of Indian paper industry, major environmental issues, waste generation and its management, cleaner production technologies and role of waste management information system in the reducing the wastage and improving the productivity.

MAJOR CHALLENGES AND SHORT COMINGS

Paper indsutry is passing throught bad times due to market recession. Steep hike in the cost of almost all the inputs of paper industry is posing serious threat to very existence of paper mills. With recent stringent environmental regulations especially with discovery of dioxins and furans, have posed another major challenge to Indian paper industry where still conventional bleaching technologies are being used by large number of mills. Decline in availability of

Department of Chemical Engineering,
University of Roorkee,
Roorkee-247 667

TABLE-1

MAJOR POLLUTANTS AND SOLID WASTES FROM PULP AND PAPER INDUSTRY

General	Source	Specific Pollutants	Typical generation/emission
Water Pollution	Bamboo and wood washing, cooking and washing section, bleaching section, evaporator, recovery furnace, causticising section, bleach liquor preparation, paper machine, power plant, lime kiln, caustic chlorine plant, effluent treatment plant	High BOD, COD, pH, suspended solids, chlorinated organics Resin acids : abietic, dehydroabietic isopimaric, palusric, primaric, sadaracopimaric and neoabietic; Unsaturated fatty acids : oleic, linoleic, linolenic and palmitoleic acid; Chlorinated resin acid : mono and dichlorodehydroabietic acid, dichlorostearic acid; Diteropene alcohols: primarol, isoprimarol, abienol etc; Juvabiones: Lignin and lignin degradtion products; Fugitive toxicants: sodium sulphite, hydrogen sulphide, chlorinated Phenolic compounds: 2, 4-dichloro phenol, 2, 4-dichlorophenol, 2, 4, 6-trichlorophenol, 2,4, 5-trichlorophenol, trichloroguaiacol, pentachlorophenol, Tetrachloroguaiacol, dia-and trichloro catechol; Chlorinated vanillins; chlorinated syringols; Chlorinated syringaldehydes; Genotixic compounds: 1, 3 dichloroacetone, 3-chloro-4-di chloromethyl-5-hydroxy-2, 5-H-furanone, chloroacetones, Dyes and pigments.	Large integrated Mils: kg per tonne of paper COD : 150-210, BOD : 30-50 Total solids: 100-200 Agro based paper mill: COD : 500 -1200 BOD : 90-300 Total solids : 100-250 Waste paper based mills : Suspended solid 50-70% BOD : 15-30, COD : 55-85, Waste water m^3/tonne: Large mills : 200-350 Agro based : 100-150 Waste paper based : 70-1000 Colour kg per tonne of paper : Bleached kraft : 150 Bleached thermo mechanical : 60 Bleached sulfite : 60
Gaseous Pollution	Cooking, brown stock washing, bleaching evaporators, recovery furnace, smelter, causticising section, lime kiln, power plant, chlorine dioxide plant, direct contact evaporator.	Hydrogen sulfide, methyl mercaptant, dimethyl sulfide, dimethyl disulfide, SOx, NOx, chlorine, chlorine dioxide, CO.	Recovery furnace : Dust, 450-1000 mg/m^3 SO_3 : 10 mg/Nm^3, H_2S : 32 mg/Nm^3; Mercaptan : 20-30 mg/Nm^3; Total reduced sulphur : 600 g/Tonne
Particulate	Chipping, recovery furnace, lime handling, power plant	Wood, Bamboo and straw dust, lime, salt cake, acid and alkali mist, fly ash etc.	
Solid Wastes	Forest operation, chipping, centricleaner, causticising section, hypo preparation, bagasse depithing, waste paper handling.	Forest and agricultural residues, pith, chipper house dust, fly ash and bottom ash, screen and centricleaner rejects, hypo sludge, lime sludge, effluent plant sludge etc., brine mud	Forest residues about 40-50%, Bark : 8-15%; Bamboo & wood dust : 3-5% kg per tonne of paper : Rejects: 35-40, Lime sludge: 450-650, Grit from causticising section: 30-45, Coal ash: 70-100 hypo sludge : 60-80 ETP sludge: 180-200, Total waste: 1200-2500, Brine mud: 30-40 kg/tonne of NaOH (Hg: 8-9 mg/gm of mud, Total loss of Hg: 390 mg/tonne of caustic

TABLE-2

CLEANER PRODUCTION MEASURES IN PULPING

- RM impregnation with recycled black liquor in agro- based mills
- RM impregnation with caustic in agro-based pulping.
- Multiple loading of digester (using residue RM in rotary spherical digesters with direct steam heating)
- Reduction in solid/liquid ratio (bath ratio)
- Indirect steam for batch cooking*
- Extended delignification by rapid displacement heating (cold blow cooking system)
- Using anthroquinone (AQ) as cooking aid in agro-residue based mills.
- Neutral ammonium sulphite cooking.
- Alkaline sodium sulphite cooking.
- High yield pulping viz., mechanico-chemical pulping for unbleached paper.
- Optimization of cooking process (i.e., operating at required steam pressure, temperature, chemical dosing).
- Screw press for removal of concentrated black liquor stream from pulp.
- Twin wire belt press for pulp dewatering.
- Vacuum filter washers for washing of pulp.
  With barometric leg
  With vacuum pump
- Segregation of initial thick black liquor from deckers and its recirculation to the extent possible.
- Anaerobic treatment of black liquor.
- Chemical recovery from black liquor (agro-residue-based small mills)
- Hot stock refining.
- Recooking of knots for unbleached papermaking (forest-based mills).
- Conversion of lignin to ligno-sulphonate.
- Recovery of lignin for land application.
- Counter-current washing system for bleaching.
- Sequential chlorination (substitution of chlorine, in first stage bleaching, with chlorine dioxide).
- Bleaching with sodium hypochlorite (NaOCl)
- Bleaching with H_2O_2
- Oxygen assisted bleaching
- Bleaching with ozone
- Bio-bleaching
- Provision of hot water for maintaining bath ratio in digester, recovered form D.G. set waste heat.
- Insulation of digester.

forest raw material and energy resources has further added to the problem. Rising cost of inputs, stringent environmental regulations, poor infrastructure facilities have resulted in closure of many paper mills. Some of the major problem, which are responsible for poor gorwth of paper industries are:

- Rising cost of inputs: fibrous raw materials, energy, chemical, labour
- Uneconomic size and obsolete technology in many mills.
- High cost of production and poor productivity
- Capital effectiveness
- Poor instrumentation
- Low availability of forest raw materials and poor forest management.
- Poor recycling of waste paper.
- Lack of recovery of chemicals from agro-based black liquor.
- High energy consumption.

ENVIRONMENTAL ISSUES AND ENVIRONMENTAL MANAGEMENT IN PULP & PAPER INDUSTRY

Due to environmental pressure and stringent regulatory parameters, and market pressure for eco-friendly product environmental issues has emerged as

TABLE-3

CLEANER PRODUCTION MEASURES IN CHEMICAL RECOVERY

- Optimise foul condensate recovery
- Provision of lime kiln for calcining lime mud.
- Avoiding lime sludge spillages in mud washing.
- Replacing multi-effect evaporator with falling film evaporator

a major challenge and will continue to be single most important factor influencing the technological change in pulp and paper industry. However, the problem in Indian paper mills is quite complex due to low average capacity of the mills in India especially the agro-based mills. Majorities of mills in India is still using the conventional pulping and bleaching process and have higher consumption of fibrous raw material, water, chemicals, steam etc. resulting in higher generation of waste water. Major environmental issues in Indian paper mills are:

- Deforestation
- Large use of water and generation of large volume of wastewater.
- Generation of toxic and colour effluents.
- Lack of recovery system in agro-based paper mills
- Higher pollution load in agro-based mills.
- Emission of particulate matter.
- Generation of large amount of solid wastes.
- Poor recycle of waste paper.

Efficient waste management is conceptualized as a multi disciplinary activity and comprises quick identification of the waste generated/caused, economic reduction, efficient collection and handling, optimal reuse and recycling and effective disposal leaving no

TABLE-4

CLEANER PRODUCTION MEASURES FOR STOCK PREPARATION AND PAPER MAKING

- Using poly-aluminium silicate-sulphate (PASS) as sizing chemical instead of alum.
- Adoption of alkaline neutral sizing to enable making high ash content paper.
- Consistency indicator.
- Consistency regulator.
- Substituting existing dyes with less toxic or non-toxic dyes.
- Use of dye fixing agents.
- Installation of level controllers and retaining walls for intermediate chests.
- Prevent over refining.
- Prevention of pulp spillage from paper machine headbox by proper positioning of the guard near the ends of mesh.
- Fine-tuned dilution contract at fan pump.
- Provision of high consistency pump in couch pit.
- Controlled water pressure for edge cutting nozzle.
- Double felting to reduce press picking.
- Recycling couch decker filtrate in pulp washing
- Avoid fan pump pit overflow by providing level control in fan pump pit or recycling overflow to couch pit.
- Recycling wire pit water in showers.
- Removal of sand inerts from centri-cleaner wastewater.
- Provision of better nozzles in cleaning showers.
- Adjustment of paper width by edge-cutting nozzles.
- Installation of broke pulper in paper machine.
- Installation of additional press roll set.
- Timely replacement of upper press roll to reduce press picking.
- Provision of high velocity hood in steam dryer.
- Save-all for fibre recovery.

environmental problem. Waste generation in pulp and paper mill can be describe not only in terms of the conventional parameters like material waste but also energy waste, capital waste, manpower/skills waste.

Identifying the true causes of emissions, discharges and wastes is critical to an effective waste management program. Some of the basic waste monitoring system are [2]:

- Resource wise waste monitoring
- Stage wise waste monitoring system
- Product wise monitoring system
- Equipment/machinery wise waste monitoring
- Process wise waste monitoring system
- Employee wise waste monitoring system.

Major wastes from pulp and paper indsutry is given in Table-3. Apart from these wastes there is considerable waste in Indian paper mills in the form of energy material and manpower. Energy consumption in Indian paper mills on average is 150-200% high in comparison to the paper mills in developed countries [3]. Similarly average capacity if India paper mills is low as compared to paper mills in developed countries as well as Asia pacific region. As of 1995 average size of paper mill in India was 10,400 tonnes/ year compared with 85,000 tonnes/year in Asia and Pacific and 300,000 tonnes in Europe and North America [4]. Higher energy consumption in Indian paper mills is due to low capacity plant, low capacity utilization, number of small capacity equipments, comparatively lower unit is higher consumption of energy inputs, availability of poor quality of coal, larger number small capacity digesters, lack of blow heat recovery system, poor washing, higher consumption of steam in evaporators and paper machines. Manpower per tonne of paper in Indian mills is also high, especially in old mills.

A general objective is designing the waste management in pulp and paper industry include.

- Minimization of the resource loss which may be in the form of raw materials, energy, manpower, captial
- Cleaner technology with maximum recycling and reuse of the wastes.
- Effective utilization of solid wastes.

Some of the measures for waste reduction are

- Recognize the waste
- Determine the true cause
- Plan corrective measure
- Eliminate the cause
- Establish controls to prevent reoccurrence.

Effective waste management allows in integrated approach not only to the five basic functional elements of waste management but to the problems arising at the interface with the management of energy, conservation of raw material, environmental protection, economic factors. Waste management helps in keeping the accounts of the working of the whole system and providing necessary data and information. Fig. 1 shows the waste management hierarchy [5]. Element of successful waste minimization program is given in Flg. 2 [6].

INNOVATION IN TECHNOLOGY FOR WASTE MANAGEMENT

There has been significant innovation and developments in technology in pulp and paper manufacture to improve quality, minimize the energy consumption, reduce the toxicity of bleach plant effluent, and waste water generation, reduce the colour in the effluent, to improve better recycle.

TECHNOLOGICAL DEVELOPMENT IN PULPING AND BLEACHING

Pulping and bleaching has been one of the major areas where major technological development has taken place in the pulp and paper industry. Some of the technological development in pulping and bleaching for reducing toxicity and waste generation are:

Process modification	Delignification of pulp as much as possible before chlorination stage to decrease residual lignin, improved brown stock washing and screen, improvement in bleaching sequence to reduce or use of eleminate the elemental chlorine.
Control of outside Contamination	Elimination of use of defoamer containing dioxin precursers

TABLE-5

CLEANER PRODUCTION MEASURES IN UTILITIES

- Use of soft water as boiler feed water.
- Insulation feed water tank and condensate recovery tank.
- Proper insulation of steam pipe stem.
- Regular maintenance of DG set.
- Optimizing co-generation system by upgrading/ modernization.
- Waste heat recovery from DG set.
- Installation of maximum demand controller.
- Provision of fuel (rice husk) feed controller mechanism in boiler.
- Supply of make-up-water in condensate.
- Combustion optimization in boilers.
- Insulation of condensate return line.
- Avoidance of condensate and steam leakages.
- Rationalization of steam and condensate lines.
- Micro-processor bases excess air controller for boiler.

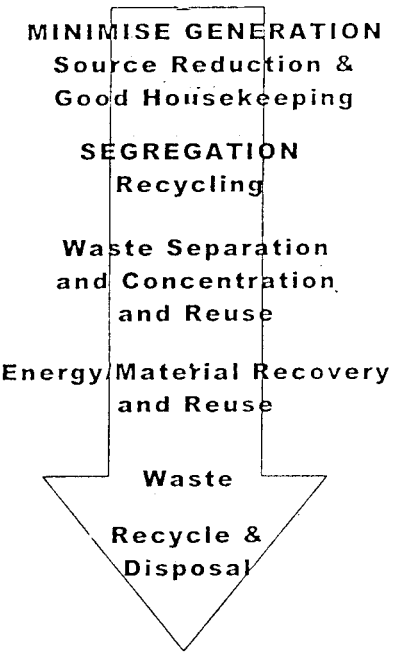

Fig. 1 : IPA Waste Management Hierarchy

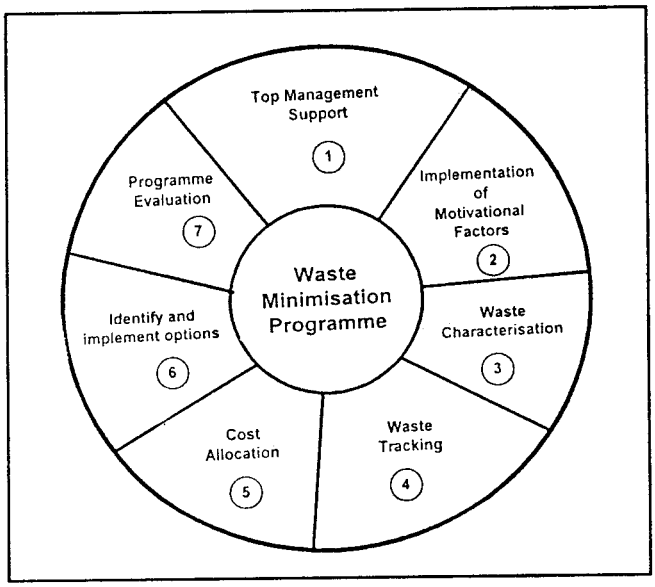

Fig. 2 : Elements of Successful Waste Minimisation Programme.

External control measures	Stablisation ponds, activated sludge, aerated lagoons, membrane process, adsorption, electrochemical process.

CLEANER PRODUCTION

Cleaner production is the continuous application of an integrated preventive environmental strategy to processes, products and services to improve eco-efficiency and reduce the risks to humans and the environment [7]. UNEP in the Asia Pacific region has explored the concept of cleaner production technology for achieving the sustainable development. And has published two documents- "Cleaner production at pulp and paper mills : A guidance manual" and "Cleaner Production technology- technology fact sheets. A general approach to cleaner production is given in Fig. 3. Various cleaner technologies are given in Table 2, 3, 4, 5 [7, 8].

ZERO DISCHARGE

Zero discharge minimize consumption of fresh water, reduce or eleminate discharge of pollutant, more availability of water helps in better compliance with environmental standards. Reduction in the wastewater affects both effluent treatment and fresh water costs. Minimization of water use can be achieved by reuse, regeneration and reuse and regeneration and recycling. Main philosophy of zero discharge is

- To minimize waste generated as far as is technologically and economically feasible.

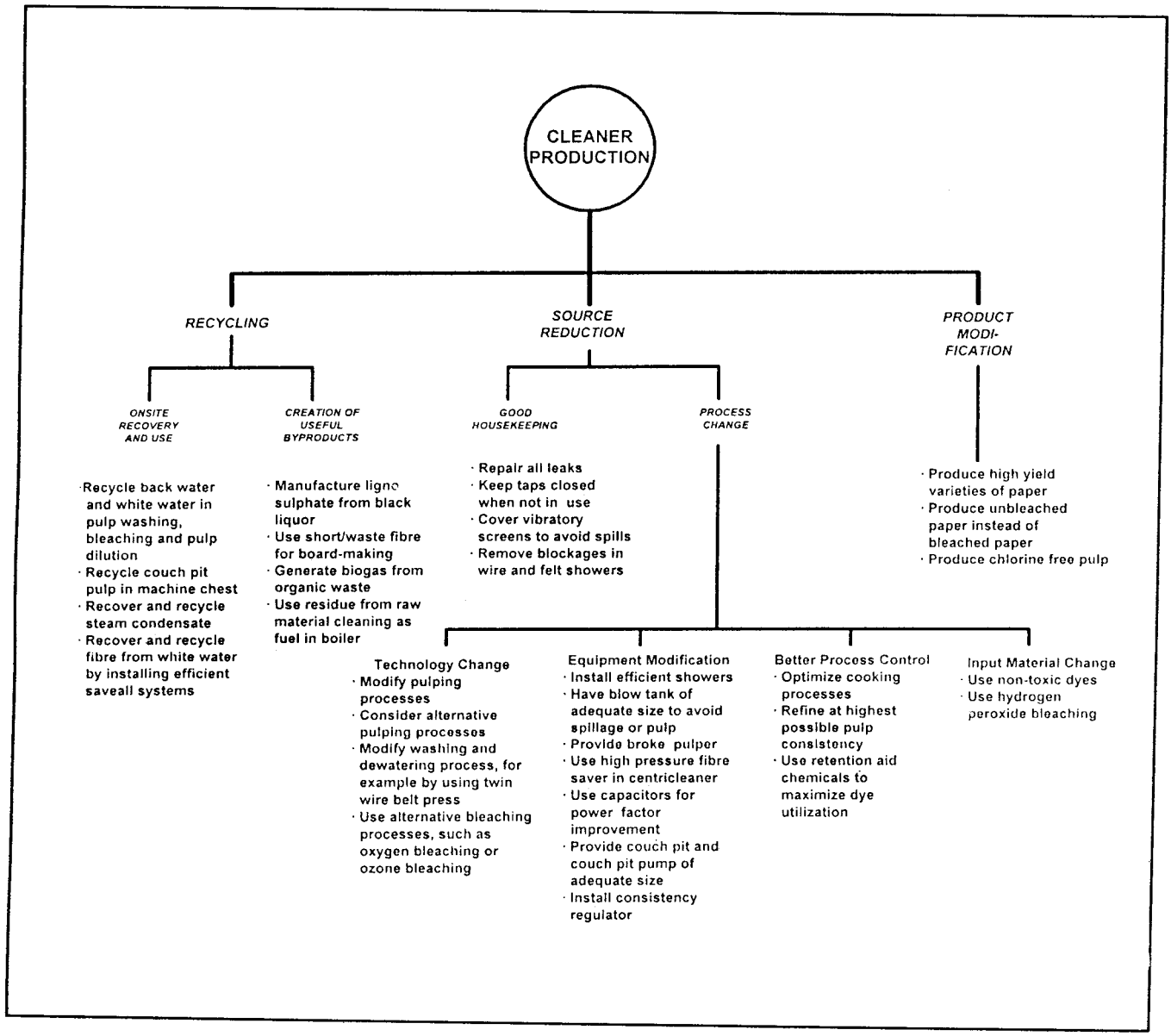

Fig. 3 : Cleaner Production Technology

- Effective use of the waste which is generated.

Application of zero discharge program through closed loop wastewater recycling system and polishing stage treatment of the effluent has been very successful in many mills which has resulted in considerable reduction water consumption and waste water generation. There is large scope in recycling and reuse of wastewater from paper machines. Closing white water system results in reduced fresh water consumption, lower loss of fibre, fines and chemicals consumption, reducing cost of treating white water, better compliance with environmental, reduced waste treatment cost.

INNOVATION IN ENERGY MANAGEMENT TECHNOLOGY

This is one of the areas where there is still lot of scope for reducing the energy consumption in pulp and paper mills. Reducing the energy consumption will result in the minimization of waste of energy inputs especially coal and fuel oil. Some of the major innovation required in Indian pulp & paper mills are

- Upgradation of digester and adoption of extended delignification.
- Upgradation of evaporator, use of vapor

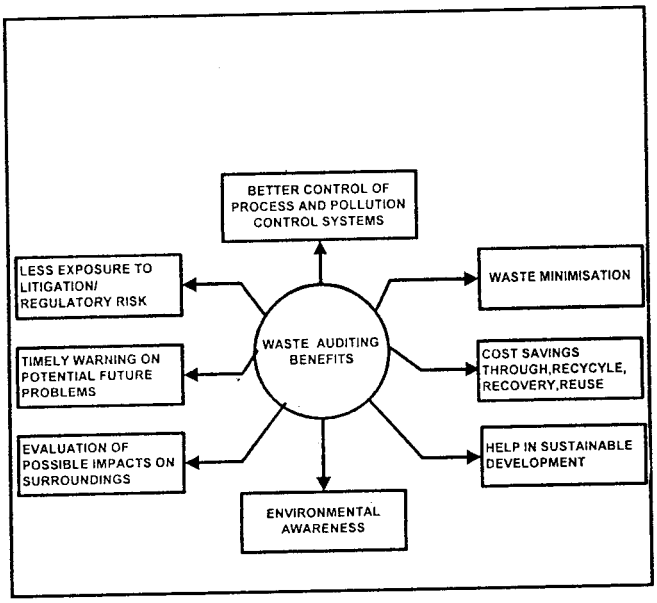

Fig. 4 : Waste Audit Benefits

recompression evaporator; falling film evaporator.

- Retrofitting recovery furnace for higher thermal efficiency and higher recovery.
- Improvement in washing to have high solid content of black liquor.
- Improvement in bleach washer.
- Upgradation of refining equipment.
- Installation of recovery system in agrobased paper mills.
- Reburning of lime sludge.
- Use of combustible waste in boiler.
- Proper condensate recovery.
- Installation of modern press section for increased off press dryness.
- Energy audit and energy information system.

SOLID WASTE MANAGEMENT

Solid waste generated at various stages of pulp and paper making during in-plant operations are : Dirt, sand and other impurities from bamboo washing; Bamboo and wood dust in chipper house; pith from bagasse pulping plant; knotter, screen and centricleaner rejects in pulp mill; Lime dust from lime handling and slaker; grit, dregs, lime sludge in recovery section; partculate matter from recovery furnace, dissoloving tank, lime kiln; centricleaner rejects from paper machines; contaminated material from waste paper plant; sludge from effluent treatment plant; sludge from raw water clearifier; boiler bottom ash and fly ash from power generation plant. Although the solid wastes generated at various stages of pulp and paper manufacture are unavoidable, however, with better in-plant control measures and good house keeping and general consciousness at all levels, the quantum of solid waste generated can be reduced to a great extent.

WASTE AUDIT

Waste audit is a management tool comprising a systematic documented, periodic and objective evaluation of how well organizations, management systems and equipment are performing. Waste audit is for introspection, self discipline, enlightmented self interest. It helps in achieving maximum resource optimization, improving the process performance and highlights process in efficiencies and area of poor management utilization. Benefits of waste audit is given in Fig. 4 [9]. Some of the advantage of waste audit are [9, 10].

- Reduced exposure to litigation and regulatory risk (e.g. prosecutions, penalties, etc.); facilitating comparison and interchange of information between operations or plants.
- Increasing employer awareness of environmental policies and responsibilities.
- Highlights process inefficiencies and areas of poor management.
- Identifying potential cost-savings including those resulting from waste minimization;
- Evaluating training programs and providing data to assist in training personnel;
- Permits the development of cost effective waste management strategies.
- Helps in setting targets for waste reduction and prioritize waste reduction measures.
- Providing an information base for use in emergencies and evaluating the effectiveness of emergency response arrangements;

- Assuring an adequate, up-to-date environmental data base for internal management awareness and decision making in relation to plant modification, new plants etc;
- Enabling management to give credit for good environmental performance;
- Helping to assist relations with authorities by convincing them that complete and effective audits are being undertaken.
- Facilitating the obtention of insurance coverage for environmental impairment liability.
- Facilitating management control on environmental practices.
- Assessing compliance with company policies including meeting regulatory requirements.
- Safe guard against waste and losses.

Thus by implementing waste audit regularly minimization of resources consumption and waste generation can be achieved.

WASTE MANAGEMENT INFORMATION SYSTEM

Development of an information system which is an integrated, user machine system for providing information to support operations, management and decision making functions in an organization has now become one of the important components of infrastructural necessities. Informational data base regarding waste is often lacking or non existence in many plants. A good data base system allows quick, reliable and economic assessment of waste generation rates helps in development of proper waste monitoring system, accurate measurement of quality and quantity of waste and development of more rapid methods of sampling and analysis and standards on waste. In new plants design of waste management data acquisition and a database should be incorporated into the overall plant design for the start.

Waste management information system is an integrated, user machine system for providing information to support operations, management and decision making functions in an organization related to waste. The objective of good waste management information system are:

- To motivate operating personals in minimizing the waste generation.
- To provide information essential to the allocation of costs to specific process and products.
- To facilitate in identification of sources of losses in the form of raw material, fuel, electricity and other inputs and cost reduction investment opportunities.
- To provide information regarding the true causes of higher waste generation.
- To helps in implementation of corrective measures for improving waste management.
- To establish controls to prevent recurrence of wastes.

Waste management information system will help the operators to control costs on day to day basis or on hour to hour basis by comparing actual consumption per tonne with standards or target. Waste management information system should focus on controllable cost and controllable losses. Energy management information system has been already implemented in mills in developed countries and they have been able to reduce their energy consumption substantially [11].

CONCLUSIONS

Although waste generation is unavoidable, however with effective waste management, which involves three basic principle 3R-, reduce, reuse and recycle in addition to end pipe treatment the wastes can be minimized. Paper industry will have to go for a short term and long term measures to minimize the wastes. In order to have an effective waste management paper industry will have to database system along with waste audit for monitoring and controlling the waste. Paper industry will have to adopt various cleaner technologies for reducing/minimizing/ eliminating the waste which may be in the form of material, chemicals, energy inputs, manpower etc. In view of the increasing environmental concerns steps will have to be taken to bring complete harmony with the environment. We must keep in mind that waisitivity is inversely proportional to productivity. For greener world we will have to go for cleaner production and shift our focus form **"should now act"** to **"must now act"**.

REFERENCES

1. "TERI energy data Directory & Year book 1999/

2000" published by Tata Energy and Resources Institute, New Delhi.

2. Sushil "Waste management: a system perspective" "Industrial Management & data system Number 5, MCB University Press (1990).

3. Narsimha Rao, G.R. IPPTA 12 (2): 1(2000).

4. Appita Journal 50 (No. 1) : 5 (1997).

5. "Developing and maintaining a pollution prevention program" Case, L. Mendicino, L., Thomas, D. in Industrial Pollution Handbook, Ed. Freeman H.M., McGraw-Hill Inc, New York (1995).

6. Guyer, H.H. "Industrial processes and waste stream management" John Wiley Science, New York (1998).

7. "Cleaner Production at pulp & paper mills: A guidance manual" UNEP (1997).

8. "Cleaner Production at pulp & paper industry-technology fact sheets" Jointly published by UNEP regional office for Asia and the Pacific and School of environment, resource and development, Asian Institute of Technology (1999).

9. "Environmental auditing in the polluting industries" CPCB Program objectives series Probes /51/1994-94, CPCB 1998.

10. Modak, P.M. IIChE Bombay Regional Center Bulletin (1995).

11. Robb, G.A., Robb, C.A. Pulp & Paper Canada 9792) : 51 (1996).