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ENVIRONMENTAL POLLUTION DUE TO PULP AND PAPER INDUSTRY

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Abstract :

Pulp and paper industry consumes huge amount of natural raw materials and generates large volumes of gaseous, liquid and solid wastes. It is rated to be one of the highly polluting (in top 20's) industries of our country. This paper presents an overview of the environmental pollution problem due to pulp and paper industry and advocates for the persual of the wasteless processing through good house keeping, good water management, effective waste recycling, process modification etc.

Introduction

Environmental pollution is one of the major problems which mankind is facing due to rapid industrialisation, urbanisation and rise in living standards of people. Natural water bodies, atmosphere and land have been seriously affected due to over exploitation of natural resources and increasing waste generation. Paper is an essential commodity for socioeconomic development of a country. It consumes huge amounts of natural raw materials — cellulosic, coal, lime, water and chemicals, etc. During various manufacturing operations huge volume of liquid, gaseous and solid wastes are discharged into environment causing serious concern. Significance of hazards from paper industry can be realised from the fact that it is among twenty highly polluting industries of our country.

India is having about 288 paper and pulp units with installed capacity of 27.5 lakh tonnes, production during 1987 was only 16.8 lakh tonnes with capacity utilisation of only 61.1% [1]. Per capita consumption of paper is 2.2 kg which is likely to increase to 4.5 kg by 2000 A.D. [2]. Profile of Indian paper industry is given in Fig. 1 [3]. Large integrated paper mills which account for 60 % of total production utilise hardwood bamboo and waste paper and are based on kraft pulping process. Sulphite pulping is being used only by one mill. Small paper mills utilise rice straw, wheat straw, grasses, jute sticks, hessians, waste paper, etc. and use soda pulping and are not having chemical recovery system. Newsprint mills utilise about 25-30 % chemical pulp and 70-75 % mechaincal pulp from stone ground pulping, thermomechanical pulping, chemimechanical pulping and use bamboo, hardwood, bagasse as raw material. Bleaching sequences used are CEHH or CEH by large integrated mills and CEH or hypochlorite bleaching only by small mills.

Environmental degradation arising out of pulp and paper manufacture like any other industrial product can be grouped under three subheads — off-plant, in-plant and consumption generated pollution. This paper presents an overview of scenario of pollution due to pulp and paper manufactue in India. It also highlights the various inplant control measures, external control measures, prospect of utilisation of major solid wastes and environmental impacts of various pollutants.

Environmental Pollution Problem

Environmental pollution from pulp and paper industries has been a matter of serious concern. During manufactuer of pulp and paper large volumes of liquid, gaseous & solid wastes are discharged into the environment at various stages starting from the raw material production and procurement stage to finished product utilisation stage. Thermal stresses and noise pollution are also serious problems in these mills.

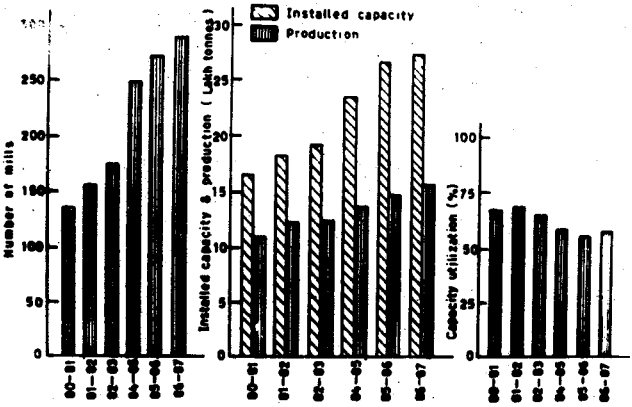

FIG. 1 - PROFILE OF INDIAN PAPER INDUSTRY.

Pollution problem during raw material procurement (off-plant pollution), during manufacture (in-plant pollution) and during consumption (consumption generated pollution) are discussed below.

Off-Plant Pollution

Off-plant pollution includes solid wastes such as cutting wases, bark, leaves, branches, etc. during cutting and procurement of wood and bamboo; deforestation and ecological upset due to forest operation; dust hazard and from debarking and forest operation; solid waste fromlimestone quarry (about 2-4 times its weight) [4] and emission of dust during limestone quarry, coal production (100gm of respirable dust per tonne of coal) [5] and lime production (100kg from rotary kiln and 4kg from vertical kiln per tonne of lime) [6]. Environmental impact of limestone an dcoal mining and magnitude and potential significance of pollution is given in Fig. 2 [7,8]. The suspended solid, BOD and COD load from wet debarking may be in the range of 3-12, 2-7, & 5-20 kg/m^3 respectively [9]. Health hazards associated with debarking operation are asthma, lung infection and nasal infection, the aetiological agent is coniosporium certicola a fungus spore found between the bark and wood trees [10].

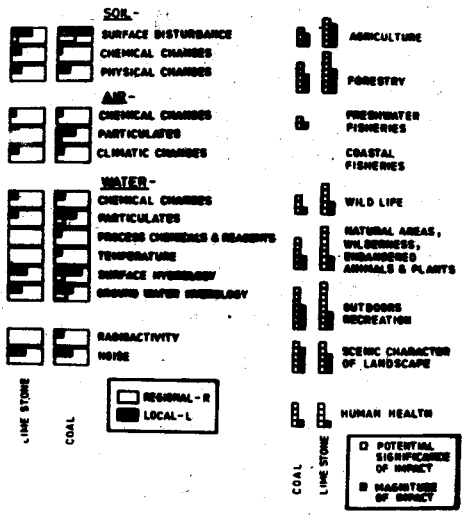

FIG. 2 - ENVIRONMENTAL IMPACT, MAGNITUDE AND POTENTIAL SIGNIFICANCE OF IMPACT OF LIME STONE AND COAL MINING.

In-Plant Pollution

Significant quantities of waste in solid, liquid and gaseous forms are generated during paper manufacture causing serious pollution of water, air and eco-system. Other factors causing environmental deterioration within plant are thermal stresses due to excessive heat and humidity and noise pollution. Sources of waste-water, air pollutant, contaminated condensate and solid waste generation are given in Fig. 3.

Water Pollution

Paper industry is a major consumer of process water and the projected water requirement by 2001 A.D. for pulp and board mills and newsprint mills is 1037 million m^3 per annum and 228 million m^3 per annum respectively. About 200-350 m^3 of wastewater per tonne of paper is discharged having high BOD, COD, pH, solid contents colour and foam. Wastewter discharge from paper industry in India is about 2.4 million m^3/d. It has around 50kg of BOD per tonne of paper equivalent to that of 1000 people per day [11].

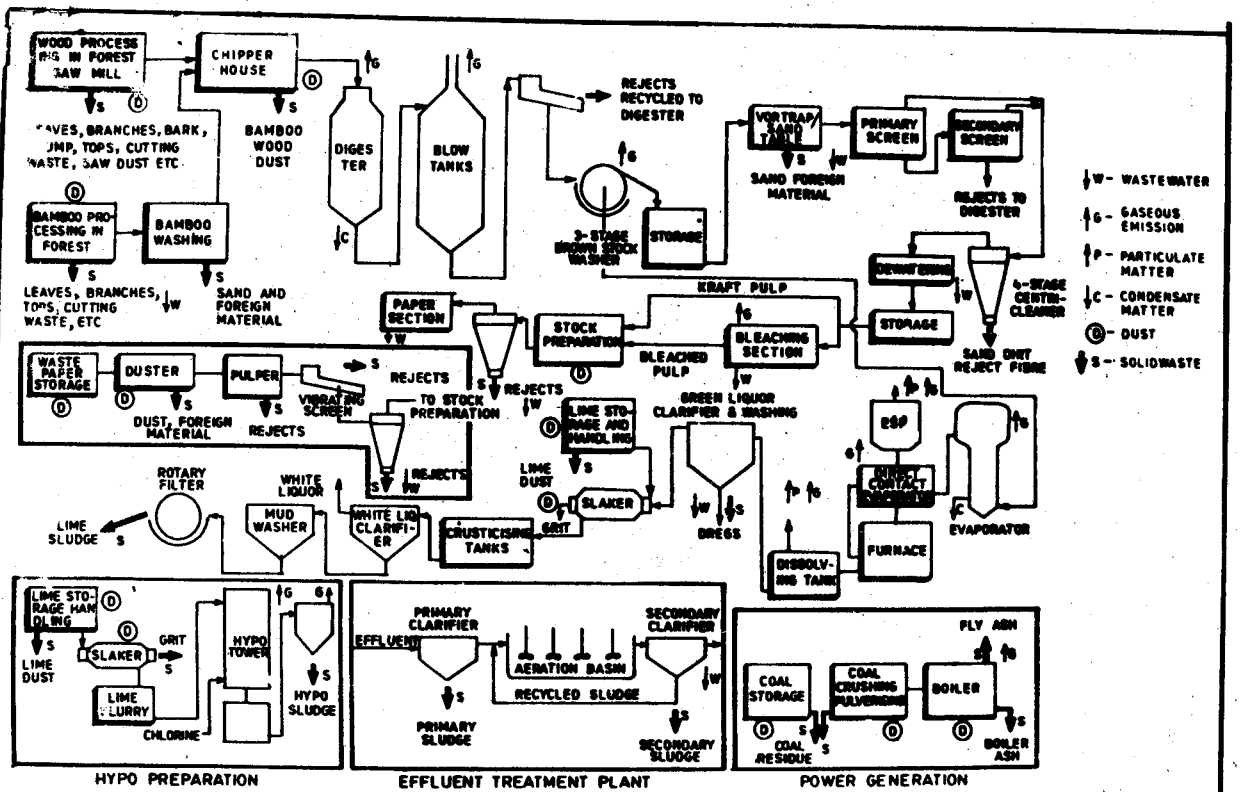

FIG. 3 - SOURCES OF ENVIRONMENTAL POLLUTION IN LARGE INTEGRATED PULP AND PAPER MILLS.

The suspended solids (SS), BOD, COD load kg per tonne of paper from Indian paper mills are: (1) large integrated mills based on bamboo and hardwood — SS: 100-150, BOD: 35-50, COD: 150-200 (ii) newsprint mills — SS: 100, BOD, 45-50, COD: 135-140 (iii) small paper mills based on agricultural residues — SS: 90-240, BOD: 85-270, COD: 500-1100 and (iv) small paper mills based on waste paper — SS: 50-80, BOD: 10-40, COD: 50-90 [12,13].

A relative large number of pollutants has been indentified in pulp and paper mills effluent. Major toxic compounds are resin acids, unsaturated fatty acids; juvabiones; diterpene alcohol, chlorinated lignin, resins, phenons; gentoxic compounds etc. [14,17]. Effluent colour is largely as a result of lignin and lignin degradation products such as aromatic and quinoid nuclei, carbonyl and ethylenic groups. Structures involved in formation of coloru are components of large molecular weight compounds [18]. Caustic extraction stage in bleaching is responsible for 60-70 % of kraft mill effluent colour loading. Colur discharged in Pt-Co units from various sections of a large integrated mills based on hardwood and bamboo is as follows: washing and screening: 2000, cyclean reject: 800, chlorination: 280, alkali extraction: 20,000, recovery section drain: 200, paper machine: 10, mill composite: 1000 [19]. Colour discharged (kg per tonne of product) from various processes are — kraft pulping: 25-150, kraft bleaching 100-150, NSSC pulping recovery: 100-125, sulphite pulping recovery:15-100, sulphite bleaching: 25-150[20]. Effluent load in kg per tonne of product from various mechanical processes is — stone ground wood — BOD: 10-22, COD: 22-50, SS: 10-50, refiner mechanical pulping — BOD: 15-30, COD: 23-55, SS: 10-50, thermomechanical pulping BOD: 15-30, COD: 25-60, SS: 10-50 [9]. Contaminated condensates, although less in volume, are highly concentrated. The BOD from digester and blow vapours, and black liquor evaporation may range 4.5 —9.0 kg and 9-13 kg per tonne of paper. These condensates have adverse effect on all aquatic life.

Pollution due to small paper mills based on agricultural residues is more serious as recovery of chemicals for these mills is still a big problem and these mills are not having recovery systems. The suspended solids, BOD and COD from small mills are about 2.2, 3.4 and 2.7 times the corresponding load from large integrated mills [12] and a 30 TPD small paper mills based on agricultural residue has BOD load equivalent to a 100 TPD large integrated mill.

Solid Wastes

Major solid waste from paper industry are chipper house dust, cyclean rejects, lime sludge, boiler ash and effluent treatment plant sludge. Quantity and sources of major solid wastes are given in Table 1 [20].

Air Pollution

Various atmospheric emissions include malodorous gases — hydrogen sulphide, mercaptans, dimethyl sulphide, dimethyl disulphide, oxides of sulphur and nitrogen an dparticulate matter — sodium sulphate, sodium carbonate, sodium sulphide and fly-ash. Major sources of dust emission are chiper house; digester house; lime handling in causticizing and bleach liquor; coal dust, bottom ash, fly ash in power generation plant; talcum and China clay handling; rag hosiery and hession chopper and waste paper plant (Fig.3). Particulate emission from recovery furnace and smelt dissolving tank may be in the range of 75kg-90 kg (50-85 % less than 2 u size) and 9 kg, (90 % more than 5u) per tonne of pulp, respectively [5,21]. Sources and characteristics of major air pollutants and their impact on environment is given in Table 2 [21-27]. Temperature, sulphidity, methoxyl content and pH are the various parameters affecting release of methyl mercaptan and dimethyl sulphide. Odour formation is directly proportional to the sulphur-content of cooking liquor. Other sources of air pollution may be of chlorine from bleaching section and hypo preparation plant, and becomes disastrous during chlorine leakages.

Health Hazards

Associated with health hazards are andenocarcinoma and asthma due to wood and bamboo dust, symptomatic pheumoconiosis due to talcum, and occular ulceration, bronchitis and pneumonia due to lime dust. Talcum dust in handling of bags and subsequent emptying in some Indian plants is as high as 2000mg/m^3 [10] Lime dust concentration while feeding to crusher and handling is even upto 200 times the TLV [10]. Eye irritation, bronchitis and asthma in bleaching section and caustic chlorine plant which is integral part of large integrated mills have been common in workers exposed to chlorine and sometimes it becomes highly hazardous and fatal during accidental leakages and prolong exposure. Workers engaged in waste paper sorting and dusting plant especially in case of road sweepings are also exposed to dust and suffer from bronchitis, and asthma. Mists from fresh liquor tanks, recovery furnace, smelt dissolving tank, and causticizer are also responsible for serious health hazards.

Consumption Generated Pollution

Increased use of paper board and newsprint has resulted in increased waste paper from various sources. Recovery of wste paper and waste paper products is hardly 3-6 % and rest goes to waste and forms sizeable part of municipal waste (7-8 %) [28]. Recovery of waste paper in India is only 20 % as compared to 30-40 % in advanced countries. There is urgent need to have better and efficient utilisation of waste paper. This will necessitate solution to many inherent problems contamination aesthetic etc.

TABLE - I

Major solid wastes from paper industry and their prospects of utilisation.

Solid Waste	Source	Approximate Amount	Possible ways of utilisation	
Forest residues	Wood and bamboo cutting waste	40%	Incineration, landfil, soil conditioning whole tree	Lower carbon and heating value, higher moisture, collection, transportation charge restrict it efficient utilisation.
Bark	Debarking plant	8–15%	In manufacture of activated carbon, tannins, waxes, lignin oxalic acid and fibre board; as soil conditioner; whole tree pulping; as fuel.	Pulping wood with bark results in lower Yield, higher cooking chemical, lower strength properties; some of the advantages of whole tree pulping o saving in debarking, higher black liquor and higher heating value.
Pith	Bagasse depithing	30% of bagasse	Can be used as fuel, cattle feed and for manufacture of furtural.	
Chipper house dust	Chipper	3–5%	In manufacture of chip board, particle board, vanill- in building blocks fire bricks, inferior quality of pulp, as much, soil conditioner and for incineration, cooking separately, or in small percentage with chips.	Fines result in lower yield; higher specks, alkali carryover and chlorine consumption, lower strength, fibre pickup problem.
Cyclean rejects	Pulp mill and paper section	40–50kg per tonne of paper		Contamination with sand and dirt create problem.

Lime sludge	Caustici-sing plant	0.45–0.65 tonne per tonne of paper	In manufacture of cheap quality board. In manufacture of port-land cement, masonmary cement, reburning after disilication, soil conditioning.	High alkali content causes ring formation in kilin, during production of clinker, high moisture and fineness causes jamming at various stages, higher fuel consumption.
Effluent plant sludge	Effluent plant	0.2–0.5kg solid per kg of BOD removed	and mixing with virgin pulp in small proportion, in manufacture of cheap quality board, as filler in duplex board, as soil conditioner.	sation are foaming, fluff and fibre pick up problem, lower strength, higher percentage of fine, higher ash percentage. Controlled mixing can overcome these problems.
Fly ash and bottom ash	Power generation plant	0.34–0.37 tonne per of coal burnt		
Ashes from bark bark boiler	Bark boiler	—	In manufacture of pozzolana cement, Portland Cement, brick; as soil conmditioner, adsorbent, roadfil	High carbon and alkali content causes many problems in cement manufacture, low carbon fly ash not suitable as adsorbent.
			Can be used as fertiliser,limlng material.	
Lime Kiln rejects	Lime kiln		In manufacture of binder having cementacious property	
Waste paper	Municipal garbage	6–8% in municipal waste	in inferior quality board, as filler in Dublex Board	with handling due to dust and odour and contamination with foreign material cause problem.

TABLE - II

Sources of emission of air pollutants their characteristic and effect on envirnoment and health

Pollution	Sources of emission
(weakly acidic, fouling smell, MP-82.9 O^0c BP-61.8 heavier than air flammable)	vent, washer seal tank, evaporator black liquor oxidation plant, recovery furnace, smelt dissolving tank lime kiln.
Methlyl mercaptan (weakly acidic gas BP-5.8)	-do-
Dimethyl sulphide (Non acidic BP-30^{0}C)	-do-
Dimethl disulphide (Non acid BP-118^{0}C)	-do-
Chlorine (Greenish yellow,acidic gas, BP-34.05^{0}C Heavier than air)	Bleach liquor preparation, bleach plant washer hood vent, seal tank caustic chlorine plant.
(BP-9.9^{0}C (731 mm) 59^{0}C) So2 (Acidic gas pungent odour)	**Chlorine dioxide** generation and bleach palnt power plant, recovery furnace, lime kiln

Odoar threshold value, ppb	TLV, PPM	Major effect on environment and health
4.7 Explosive conc. range in air 4.3–4.5% flammability range in air lower/upper 4.3/15.0	10	Irritant, asphyxiant auses irritation to eyes and resipiratory system, exposure to 1000 ppm may be fatal prolonged exposure may cause pulmonary adema. Repeated exposure to low concentrations, causes conjunctivities; photophobia, tearing and blurred vision, darkens exterior paints.
2.1	10	Offensive adour, causes nausia and headache, high concentration can produce unconsciousness and rapid pulse, produces toxic and flammable vapour on reaction with steam.
1.0 Explosive conc. range in air 3.9–21.3		Highly toxic, dangerous when exposed to heat or flame, when heated to decomposition it emits highly toxic fumes of oxides of sulphur.
5.6		Offensive odour
0.314	1.0	Pungent, suffocating, bitter, corrosive gas, causes irritation to eye, nose, throat; inhalation can cause resipiratory injury. Prolong exposure cause bronchial, tuberculosis, and achen.
	0.1	Pungent, suffogating and highly corrosive irritating effect, powerful oxidiser.
	5	Dangerous to eyes, causes irritation corrosive, damage may cause edema of lungs and damage to vegetation.

Environmental Protection Measures

Various environmental protection measures include water pollution control, air pollution control, solid waste treatment, and noise pollution control.

Water conservation and Pollution Control measures

Good water management is vital for economy of a mill as every drop of water that is added to paper making system incurs cost in one or several ways and each m^3 of water cost about 70-80 paise. The cost of effluetn treatment itself may be around Rs.75/- per tonne of paper or Rs.1.00 per kg of BOD removed. In a 100 TPD mill, reduction in water consumption of $10m^3$-$20m^3$ per tonne of paper will result in net saving to the tune of about Rupees 2.2-4.5 lakh per annum. There are three basic approaches — in-plant control measures and maximum recycling of back water; technological changes and external control measures, which give the most economical alternative for reducing the quantum of discharges, toxicity and colour.

In-plant Control Measures

In-plant control measures and maximum recycle of back water have been found very effective for reducing effluent load, chemical consumption and water conservation. Some of the internal control measures for water pollution control are:

1. Maximum recycling of back water at various stages, use of back water from chlorination stage and hypostage to be maximum for vat dilution during bleaching. Use of anti foam agent will solve foam build-up problem.
2. Improvement in washing and screening.
3. Maximum recycle of condenste. Strict monitoring is need for effective recovery.
4. Prevention of accidental losses, leakages from pump gland valves, pipe line and otehr sources to be atetnded immediately.
5. Collection of spillage and recycling of concentrated spill to the system and weak spill to spill lagoon to avoid contamination of whole effluent stream. Collection and recycling from black liquor,frsh liquor and chemical dosing pump to the system and immediate repair of units have been found very effective in reducing colour and toxicity and improving recovery of chemicals.
6. Maintaining the steam pressure above digester cooking pressure and routine check up a N.R. valves and timely replacement to avoid return of cooking liquro to condensae line.
7. Metering and monitoring of water consumption of every unit.

8. Washing of wood and bamboo to avoid carryover of dust and other foreign materials to subsequent stages.
9. Separation of centricleaner rejects from main drain and collection of fibre to avoid contamination of whole system.
10. Recovery of all alkali from dregs of green liquor by centrifuge.
11. Use of back water strictly in in housepipes for floor washing and ther uses.
12. Use of clarified and treated back water for causticising at various stages in pulp mill and paper machines, especiallyfor kraft paper
13. Use of back water in waste paper pulping plant.
14. Use of evaporator condensate in causticising section, pulp washing, dreg washing, dilution in screening and centricleaning.
15. Use of contaminated back water from pulp mill and recovery section drain in coal moistening, ash quenching, surface condenser and bamboo washing.
16. Segretation of extraction stage effluent from pulp mill effluent stream.
17. Good house-keeping, general consciousness regarding water conservation and monitoring by separate cell. Some of the mills have separate cell for monitoring water consumption which has been found very effective.

Some of the problems associated with increased recycle are build-up of dissolved solid-increase in colour, odor, foaming, corrosion scaling, slime, pitch problems; suspended solid-high dirt fines, plugging of felt shower and wire resulting in reduced wire and felt life, poor drainage; and increased retention of thermal energy-increase in temperature, reduced vacuum capacity and sizing problem.

Technological Changes

Some of the technological changes in process team for reducing toxicity and colour are

—Elimination or minimum use of sulphur containing pulping procss and chlorine containing bleaching.
—Extended delignification.
—Modification of bleaching sequences which includes elimination of caustic extraction stage which is major contributor of colour and results in about 62-82 % reduction in colour.
—Use of oxygen bleaching, chlorine dioxide bleaching.
—Displacement bleaching.
—Use of anthraquinone and lower sulphur high yield pulping process.
—Total recycle concept.
—Reduction in bleached pulp brightness level.

External Control Measures

The external control measures used for waste water treatment include primary treatment for removal of suspended solids; secondary treatment for removal of dissolved solids; adsorption for removalof colouring material (Fig. 4). Among the secondary treatment, aerated lagoons and activaetd sludge treatment have been very common. Activated sludge has advantage of relative compactness, operational flexibility, however, some of the disadvantages are sensitive to shock load, excess sludge, temperamental behaviour. During recent years anaerobic treatment has received considerable interest due to low power consumption, production, of energy rich biogas, lower nutrient demand, and lower sludge. Land application of industrial effluent is common in many parts and is very promising and economical for developing countries. Three systems of land application are — irrigation, in-filtration percolation, overland flow. Soil characteristics play important role in land application of effluent. Sandysoils give highest percolation, loamy soils are suitable for irrigatioin, & clay loams for overland flow [29]. The rate of application vary with soil conditions, type of crops, climatic conditions and effluent quality.

Solid Waste Management :

Prospect of utilisation of major solid wastes from paper industry is given in Table 2. Various in-plant control measures for solid waste are

1. Better utilisation of fines from chipper house either by cooking separately and blending with virgin pulp or cooking along with chips in small proportion.
2. Timely change and replacement of chipper knives.
3. Washing and moistening of bamboo and wood to reduce dust.
4. Running of screens and centricleaners at optimum efficiency with proper pressure and dilution to have minimum fibre loss.
5. Maximum possible utilisation of recovered fibre from primary clarifier.
6. Prevention and monitoring of spillge, and overflows and collection of overflow and recycling.
7. Use of good quality lime.
8. Use of wastepaper in the system judiciously.
9. Use of fibre and filler retention aid.
10. Electrostatic precieptator and other dust collection equipments to run at maximum efficiency.
11. Moistening of coal to avoid dust.
12. Reburning of residues from chipper house and coal handling plant.
13. Monitoring of the boiler operation to have minimum unburnt coal.

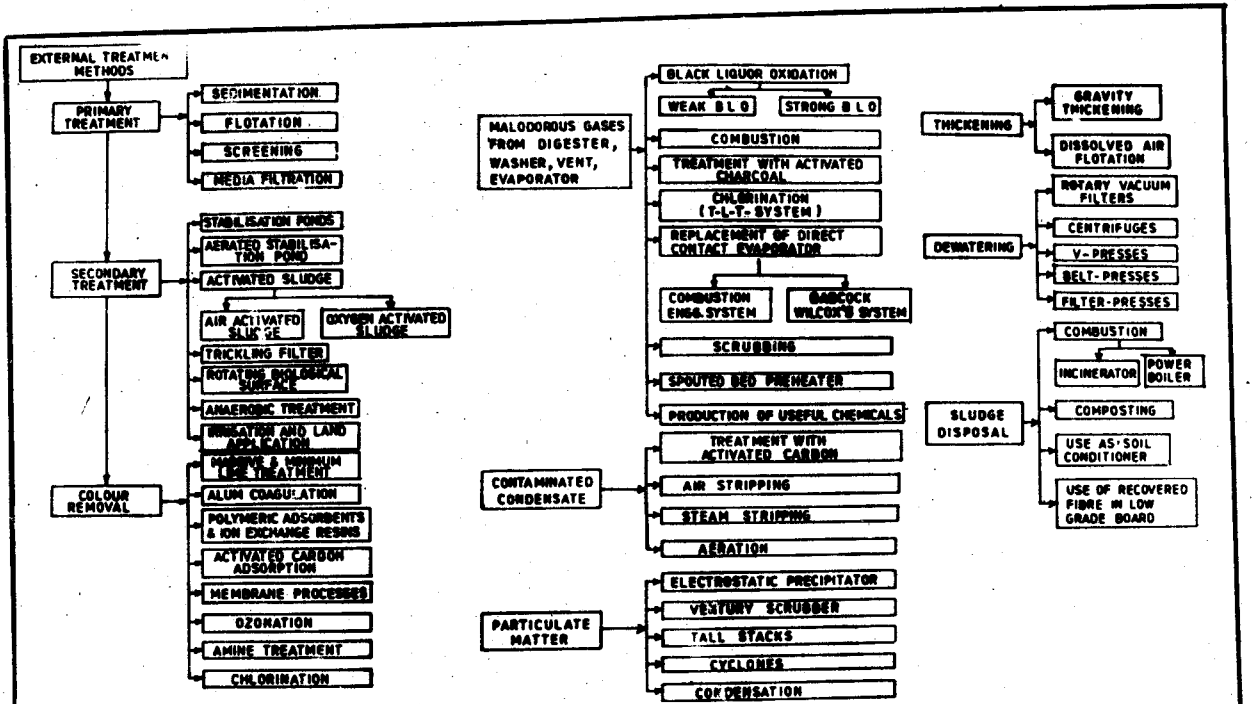

FIG. 4 - EXTERNAL TREATMENT METHODS FOR EFFLUENT, GASEOUS AND PARTICULATES EMISSION CONTROL, SLUDGE.

The cost of sludge handling and disposal constitute a major portion of waste treatment plant. Sludge from primary clarifier and secondary treatment plant contain about 95 % water. Primary sludge is high in fibre and low in ash content and easier to dewater whereas secondary sludge is difficult to dewater. Some of the common methods of sludge dewatering disposal and treatment are shown in Fig.4.

Air Pollution Control Measures

Air pollution control measures include in-plant control measures, process modifications and external control measures. Various in-plant control measures for dust emission, odour control and good working environment are:

1. Dust problem in chipper house and digester can be minimised by moistening of bamboo and wood, and provision of spray water over chips. Better working environment can be provided by better ventilation and good housekeeping.
2. Controlled relieving of digester relief gases to avoid entrainment of liquor.
3. Proper care in chlorine handling and chlorine dosing during chlorination stage to have low residual chlorine chlorine in fitrae. Installation of chlorine monitoring instrument (ORP) can help.
4. Back water system of chlorination stage should be completely sealed, proper ventilation, provision of hood and exhaust fan will help in maintaining chlorine free environment in bleaching plant.
5. Routine change of chlorine gasifier and gas line, checking of the gas line with nitrogen after all major repair and change over and checking the gas line in every shift by ammonia torch, general consciousness will help in minimising accidental leakages of chlorine.
6. Monitoring carbon monoxide below 250 ppm can help in maintaining the H^2S concentration at lower level [30].
7. Odorous sulphur compounds at the furnace outlet can be reduced if the furnace is operated with enough excess air to provide about 3 % O^2 in the flue gases and if sufficient turbulence is obtained in the oxidation zone of the furnace [31].
8. H^2S emissioncan be minimised by increasing O^2 content of the kiln gases and by reducing moisture content of limes sludge [32].
9. Maintaining low sulphudity in cooking liquor.
10. Provision of proper ventilation, exhaust fan in lime handling plant and talcum handling plant.

The major external control moisture for control of emission of odour and perticulate matter and treatment of condensate for reducing odour is given in Fig.4.

Pollution Control Strategies in India

In India the largest integrated pulp mills are having primary treatment and some are having secondary treatment systems such as aerated lagons and activated sludge method; and some are in process of implementation. However, the situation in small paper millsbased on agricultural residue is very slarming due to lack of recovery system and many mills are not having fullfledged treatment system. Air pollution control measures in Indian paper mills are yet to be given due consideration. Eectrostatic precipitator and venturiscrubber have been commonly used in the recovery furnace. However eficiency of collection vary from plant to plant and at some of the places it is at very low level.

Conclusions

The environmental pollution control measures are highly expensive and some of the existing mills may find it difficult to use them due to poor financial condition, however, with adoption of MINAS and rising public concern over environmental pollution they will have to go in for short term and long term pollution control programmes. Pollution control measures are a social responsibility. In-plant control measures mentioned above, good water management and land application of effluent may be most suitable and economical. Land application for irrigation purpose may have some public resistance, in this field various government agencies can help in persuation and educating people. Environmental hazards associated with various sources due to dust and accidental leakages can be minimised and safe, comfortable and nevironment can be provided by having good house keeping, proper ventilation, effective safety measures and proper training of concerned persons. It is felt that apart from external treatment methods what is needed is wasteless processing thruogh good house keeping, good water management, effective waste recycling, process modification etc., to have most economical approach towards the problem.

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