WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 7.523
Volume 6, Issue 5, 1414-1436. Review Article ISSN 2277– 7105

TREATMENT OF INDUSTRIAL WASTES: ISSUES, CHALLENGES & SOLUTIONS

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Article Received on
19 March 2017,
Revised on 09 April 2017,
Accepted on 29 April 2017
DOI: 10.20959/wjpr20175-8461

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ABSTRACT

Industrial wastes have done distress to the environment and human health. Industrial wastes can be organic wastes or inorganic wastes based on their components; solid wastes, semi-solid wastes and liquid (gaseous) wastes based on their species; hazardous wastes and common wastes depending on pollution characteristics. Every year, large quantities of industrial wastes are generated from the growing industries and have become a major source of pollution and serious health concerns. Developing countries face a major challenge in management and disposal of industrial waste and they specially need to confront the adequate treatment, disposal facilities and training of qualified personnel. In this review, we have highlighted the important aspects, challenges and solutions for waste generated from dairy, pulp and paper industries and very importantly we have discussed the problem and concerns of solid waste management. Keeping in mind, the problems being faced in management of industrial waste, this review could help design strategies and solution to industrial waste management.

KEYWORDS: Industrial waste, dairy industry, pulp and paper industry, solid waste management

INTRODUCTION

Dairy industry: Importance

As an attributive, the word *dairy* refers to milk-based products, processes and derivatives. A dairy farm produces milk and a dairy factory processes it into a variety of dairy products like cheese, yogurt, cream, butter milk powders etc. These establishments constitute the global dairy industry, a component of the food industry. These industries uses enormous amount of water and considered as wet industry. High amount of organic matter present in the waste water of a dairy industry.[1] The constituents present in the waste water are biodegradable. Hence the wastewater is amenable to biological treatment-either aerobic or anaerobic.

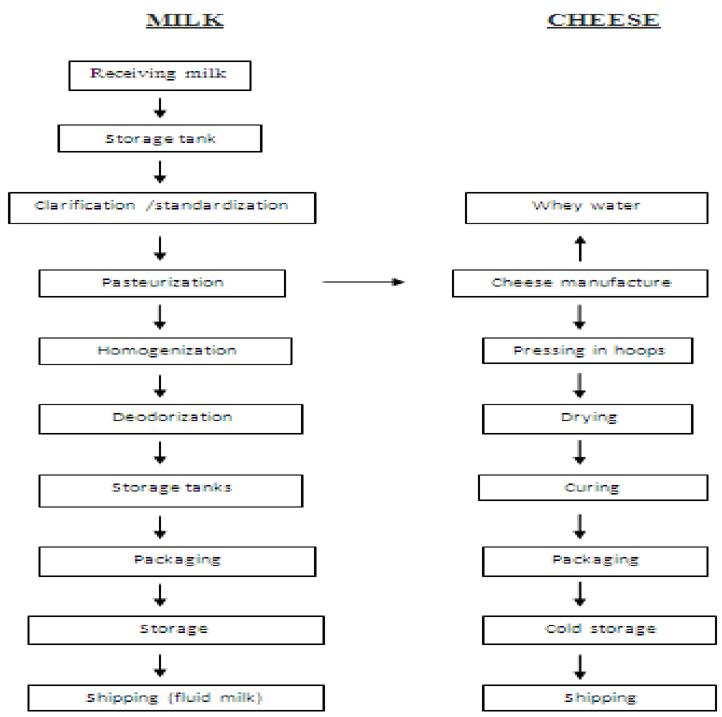
Objectives of dairy plants

The main objective of dairy plants is to process the raw milk that they receive from farmers in order to extend its marketable life.

Steps involved in processing of dairy products

Two main types of processes are employed:

1. Pasteurization: Heat treatment to ensure the safety of milk for human consumption and to lengthen its shelf-life.
2. Dehydrating dairy products such as butter, hard cheese and milk powders so that they can be stored and increasing its shelf life.[2]



Waste water characterization

For food procedures like handling, processing, packaging and storing, there will be always an inherent generation of wastewater. The quality of the waste water (i.e., pollutant strength, nature of constituents) has both economic and environmental.[3]

Waste stream can have serious ecological ramifications. For example, discharging of wastewater to a stream or river, create a eutrophic condition within the aquatic environment due to the discharge of biodegradable, oxygen consuming compounds. If this condition were sustained for a prolong time the ecological balance of the receiving stream, river or lake (i.e., aquatic micro flora, plants and animals) would be upset. Continued depletion-of the oxygen in these water systems would also result in the development of obnoxious odors and unsightly scum.[4]

The typical wastewater stream from a dairy plant has the following characteristics
Typical Waste Stream from a Dairy Plant
a) BOD - 2300 mg/l
b) S S - 1500 mg/l
c) FOG - 700 mg/l

The major constituent of waste water from dairy plants is organic material. While breaking down this organic compound, the microbes consume oxygen in the water, causes depletion of oxygen.[5] When all the oxygen in a water body is used up, as frequently happens, the decay of organic matter continues without oxygen. As a result noxious gases such as hydrogen sulfide and methane are produced. A measurement of pollutants that consume oxygen in water is called "biochemical oxygen demand," or BOD. Water with high BOD contains a large amount of decomposing organic matter.[6]

Another major pollutant is suspended solid waste, such as coagulated milk, particles of cheese curd and in ice cream plants, pieces of fruits and nuts. The measurement of this pollutant is called "total suspended solids," or TSS. These solids they settle in bottom and they impair photosynthesis in aquatic plants.[7]

The other pollutants includes are phosphorus, nitrogen, chlorides and heat. In some cases, some of the minor pollutants may be critical and may need special treatment.

Treatment of waste products/water

The dairy industry uses either aerobic or anaerobic treatment, or a combination of both, to treat the wastewater.

Aerobic systems

In aerobic treatment systems, bacteria, in the presence of oxygen, convert the organic matter of the waste to carbon dioxide, water and bacterial biomass. These treatment systems cause odours if operated incorrectly. Types of aerobic treatments include trickling filters, rotating biological contactors and various forms of mechanically aerated lagoon systems. Typical treatment parameters for an activated sludge plant treating dairy plant wastewater are 94% COD, 99% BOD5 70% TKN and 50% total phosphorus removal.[8]

Anaerobic treatment

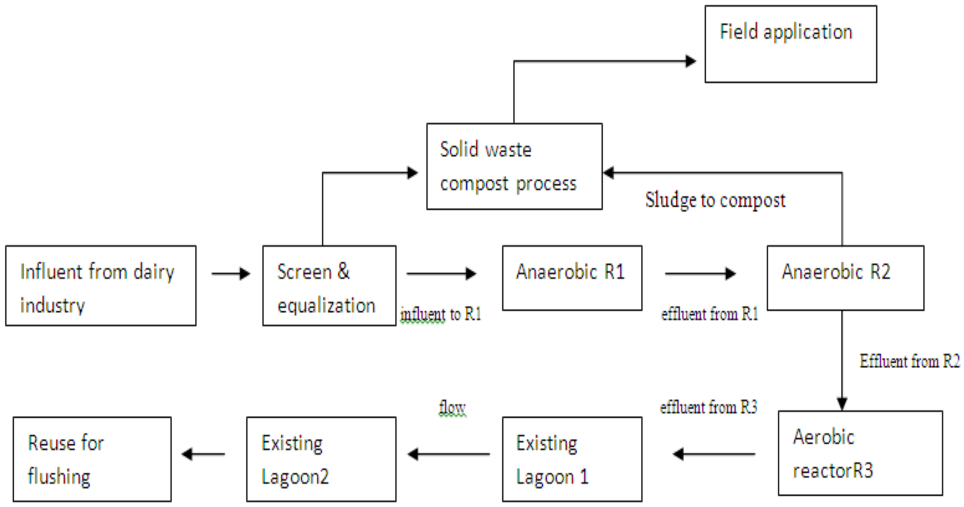
In an anaerobic treatment, an anaerobic bacterium (in the absence of oxygen) converts the organic components in the wastewater to methane, carbon dioxide and water. Organic forms of nitrogen are converted to the ammonium nitrogen form.[9]

Advantages of anaerobic digestion

The major advantages of anaerobic digestion are:

- produce a valuable byproduct (methane), which can be recovered and utilized as a fuel
- removes substantial quantities of BOD and COD without the input of mechanical energy for aeration and produce less sludge than aerobic systems.

Treatment systems flow chart



PULP AND PAPER INDUSTRY

Paper and pulp industry comprises of industries that use wood as major raw material to produce paper, pulp, board and other cellulose based products. Other than wood some papers also uses but rags, flax, cotton linters and bagasse (sugar cane residues). The major paper industries are located in North American (United States and Canada), northern European (Finland, Sweden and North-West Russia) and East Asian countries (such as East Siberian Russia, China, Japan and South Korea). Australasia and Brazil also have significant pulp and paper enterprises. The United States had been the world's leading producer of paper until it was overtaken by China in 2009.[10]

Paper is one of the major and widely used products of our society. The major source of paper is forestry industry. Its products are not only used in different industries like publishing industry and for writing on, but also has different applications like these are used to make variety of specialty papers, cardboards, brown papers etc.

The major constituents of paper and pulp industry and its characteristics

The major constituents of wood are: 1) cellulose, 2) lignin, 3) hemicellulose and 4) extractives (e.g., resins, fats, pectins, etc.).Cellulose is an organic compound, a polysaccharide consisting of a linear chain of several hundred to over ten thousand β(1→4) linked D-glucose units. Cellulose is an important structural component of the primary cell wall of green plants, many forms of algae and the oomycetes.[11] Cellulose is mainly used to produce paperboard and paper. Smaller quantities are converted into a wide variety of derivative products such as cellophane and rayon. Lignin is a complex organic chemical which provides strength to the wood. It produces energy when it is burned and hence used in paper mills. Lignin is the reinforcing compound that is deposited on tree cell walls to make the wood strong enough to carry the of the tree crown. However, it is also the compound that makes wood pulp brown, so it is removed from all wood pulp except that used to make brown paper and some cardboard. Hemicellulose is very much similar to cellulose as it provides fiber to fiber bonding in paper making. Several extractives (e.g., oleoresins and waxes) are contained in wood but do not contribute to its strength properties; these are removed during the pulping process.

The wood can be from different trees; if it is from coniferous trees (softwood) and from broad leaved trees (hardwood). These softwoods (e.g., pines, firs and spruces) imparts strength and provides with long and strong fiber which is then used for boxes and packaging. On the contrary, hardwoods are smoother, more opaque, better suited for printing but these have shorter fibre and produces weaker paper.

Manufacturing process

The process of conversion of timber into paper consists of six major steps. The first four steps convert the wood which is received in different forms at pulp mills into cellulosic fibers with some residual lignin using chemical and mechanical methods which are further used to delignifying woods, separation of fibers and removing discoloration.[12]

Step 1- Wood preparation

Wood is supplied to the mill in the form of two ways: whole logs and sawmill chips (residuals from sawmills). The bark is then removed by either passing through a drum debarker or a hydraulic debarker. Further, logs are chipped after debarking by multi-knife chippers into appropriate size pieces. The thickness of the chip is the important parameter to determine about its speed and thoroughness of the impregnation of the cooking chemicals into wood chip.

Step 2- Pulping

Pulping is the process in which major amount of delignification takes place. There are two types of pulping methods, mechanical as well as chemical pulping. There are six basic types of mechanical pulping processes: 1) stone groundwood, 2) refiner, 3) thermomechanical pulping, 4) chemical mechanical, 5) defibrated or exploded pulping and 6) recycled paper. Mechanical pulping is generally used for softwoods because of the strength imparted by long logs of wood fiber. Some of the hardwoods require chemical mechanical pulping to produce suitable groundwood pulp. Fibers separated by mechanical pulping get damaged in the process and, therefore make weaker paper or paperboard. However, since both lignin and cellulose remain intact but paper per unit volume is much higher in chemical pulping than in mechanical pulping. Pulp yields are more in mechanical, percentage recovery is 90-95% overall, but paper made from mechanical pulping is brittle and discolors with age due to presence of lignin content, which results in shorter useful life than paper produced from chemical pulping. On the contrary, chemical pulping involves treatment of wood chips with chemicals to remove lignin and hemicelluloses, to determine pulp quality and is expressed in “Kappa number”. There are two major types of chemical pulping processes that are: 1) Kraft (sulfate) pulping and 2) sulfite pulping. Kraft pulping involves treatment of wood chips in a solution of sodium sulfide and sodium hydroxide solution. In sulfite pulping, lignin is dissolved by sulfonation with an aqueous solution of sulfur dioxide and calcium, sodium, magnesium, or ammonium bisulfite cooked at high temperature and pressure.

Step 3- Pulp washing

There are several chemicals used during pulping processes, so therefore they should be removed as they may interfere with the downstream processing of the pulp. These chemicals can be really expensive to replace and can be harmful to the environment when released or dumped into the environment. The process in which these chemicals are separated from the cooked pulp is called pulp washing. There are several methods of pulp washing; some displaces chemicals in hot water some make use of pressing to squeeze out the chemicals. There was a old conventional method with a drum covered by a wire mesh which rotates in a diluted suspension of the fibers. Then the fibers will form mat on the drum and showers of hot water are sprayed onto the fiber mat.

Step 4- Pulp screening

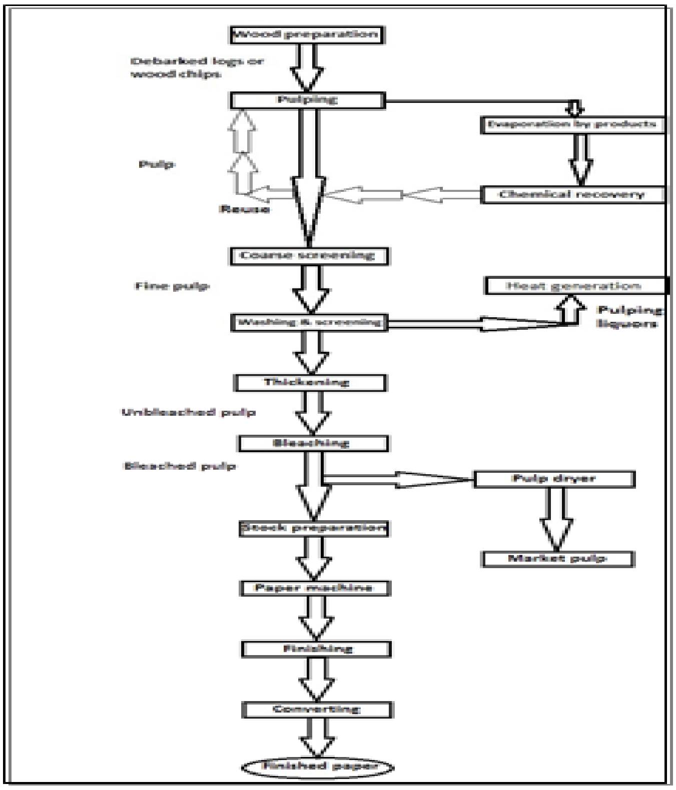
Cooked pulp sometimes contains partially uncooked fibre bundles and knots. Further, these knots and shives are removed by passing the pulp over pulp screens equipped with fine holes or slots.

Step 4- Bleaching

White papers are generally preferred for many products; however considerable amount of lignin is present in raw pulp. This is the reason for its brown color; hence discoloration or bleaching should be done to remove the left out lignin. Bleaching is a multi stage process which involves different bleaching agents like chlorine gas, chlorine dioxide, sodium hypochlorite, hydrogen peroxide and oxygen present in a particular sequence. The chemicals used in bleaching process destroy coloring impurities, but leave cellulose and lignin intact, these includes sodium bisulfite, sodium or zinc hydrosulfite, calcium or sodium hypochlorite, hydrogen or sodium peroxide and the Sulfur Dioxide-Borol Process. The final bleaching is done to improve the efficiency of the chemicals used, and to decrease the strength loss of the pulp.

Step 6- Paper making

Paper is finally made by mechanical and chemical treatment. The pulp fibres are treated by these two methods and formed into dilute suspensions, which is spread over a mesh surface, the water removed by suction then and the resulting pad of cellulose fibres pressed and dried to form paper.



Description of how waste is generated and its characteristics

Source	Raw material	Waste type	Waste characteristics/major pollutants
Wastewater treatment plant	White water, reused water	Sludge	Organic fractions consists wood fibers and bio sludge
			Inorganic fraction consists clay, calcium carbonate and other materials
			20-60% solid content pH=7
	Washwater and fiber	Acid plant waste	VOC (Terpenes, alcohols, phenol, methanol, acetone, chloroform, methyl ethyl ketone[MEK])
Caustic process	Acid sulphite liquor or alkaline sulphate or neutral sulphite	Dregs, muds	Green liquor dregs consisting of non-reactive metals and insoluble materials; lime mud
Power boiler	White water	Ash	Inorganic compound SO_2, NO_x, fly ash, coarse particulates
Paper mill	Fresh water	Sludge	Colour waste and fiber waste including slowly biodegradable organics such as cellulose, wood fibers and lignin
Chemical pulping process	Acid sulphite liquor or alkaline sulphate or neutral sulphite	Blow systems emission, smell tank, lime tank, kiln,	VOC (Terpenes, alcohols, phenol, methanol, acetone, chloroform, methyl ethyl ketone[MEK])

		Recovery furnace	Reduced sulphur (TRS)
			Organo-chlorine compounds
Bleaching	Bleaching in other necessary chemicals	Chlorine, chlorine dioxide	VOC (methelyne chloride, trichloroethane, chloromethane, acetone, chloroform, methyl ethyl ketone[MEK])
Evaporator	Acid sulphite liquor or alkaline sulphate or neutral sulphite	Evaporation emissions, heat	Evaporator noncondensibles (TRS, volatile organic compounds: alcohols, terpenes, phenols)
Recovery furnace	Dreg lime grits	Smelt tank, lime kiln	Fine particulates, TRS, SO_2. NO_X
Calcinating (lime kiln)	Alkaline sulphate	Smelt tank, lime kiln	Fine and coarse particles

Wastewater characteristics of the pulp and paper industry

S.no	Type of industry	Major pollutants	Average concentration of Pollutants before treatment in mg/l	Average concentration of Pollutants after Treatment in mg/I	Wastewater flow in m^3/tonne of product
1.	Large paper Mill	SS	650	150	175
		BOD	400	30	
		COD	700	350	
2.	Agro- based Mills	SS	2000	300	150
		BOD	1250	175	
		COD	2500	450	
3.	Waste-paper based Mills	SS	300	70	60
		BOD	400	20	
		COD	600	120	

Source:
(a) Information received in Central Pollution Control Board from various units
(b) Comprehensive Industry Document for Large Pulp & paper Industry: COINDS/36/2000-01, CPCB, Delhi.
(c) Comprehensive Industry Document for Small Pulp & paper Industry: COINDS/22/1986, CPCB.Delhi.

Treatment of paper and pulp waste

Waste produced during pulping process contains organic materials and also bleaching agents or biosites so therefore effluents should be treated before disposing to the streams and oceans. Although the best way is to minimise the waste generation from the mill and to recycle, end of pipe pollution treatments are still necessary. The main treatment application from the pulp and paper industry wastewater is the primary and secondary treatment.[13]

Pre-treatment

It usually refers to any treatment the wastewater is subjected to before entering a conventional wastewater treatment plant. Pre-treatment typically involves operations connected to separation of very coarse or easily separable materials and/or water conditioning before discharging to a treatment plant (e.g., equalization). Pre-treatment of industrial wastewaters commonly refers to any treatment required to make the water acceptable for discharge to a treatment plant.

After pre-treatment the wastewater is subjected to primary, secondary and tertiary treatment.

Primary treatment

It pertains to the removal of easily separable materials such as oils, floating solids, or quickly settling solids, and the preparation of the wastewater (e.g., pH adjustment) for subsequent treatments. Primary treatment involves operations such as equalization, neutralization, sedimentation, oil separation and floatation. The purpose of this step is to remove suspended solid such as bark particles, fiber, fiber debris, filler and coating materials. Dissolved air floatation and filtration are the other option as primary treatment for pulp and paper industry.

Secondary treatment

It is typically the most important part of the process, and is used primarily to remove the bulk of the suspended solids, organic materials (both hazardous and non hazardous) and other soluble materials. Biological treatment constitutes the process of choice during secondary treatment of wastewater.

Oxidation pond

Also known as stabilization ponds or lagoons. Used for simple secondary treatment of effluents. Within an oxidation pond heterotrophic bacteria degrade organic matter ¡n the waste which results ¡n production of cellular material and minerals. The production of cellular material and minerals supports the growth of algae ¡n the oxidation pond. Growth of algal populations allows further decomposition of the organic matter by producing oxygen. The production of this oxygen replenishes the oxygen used by the heterotrophic bacteria. These systems are basically used for removal of BOD, low molecular weight AOX and fatty acids of full scale applications.

Activated sludge system

Activated Sludge is a widely used aerobic method of wastewater treatment. After primary settling, the waste stream is brought to an aeration tank. Air is put in and/or there is mechanical stirring which provides aeration of the waste. Sludge from a previous run is usually reintroduced to the tanks to provide microorganisms. This is why it is called activated sludge. During the period ¡n the aeration tank, large developments of heterotrophic organisms occur. In the activated sludge tank the bacteria occur in free suspension and as aggregates or flocs. Extensive microbial metabolism of organic compounds in the wastewater results ¡n the production of new microbial biomass. Most of this biomass becomes associated with flocs that can be removed from suspension by settling. A portion of the settled sludge ¡s recycled and the remainder must be treated by composting or anaerobic digestion. This conventional treatment system is used in treatment of pulp and paper wastewater types in order to remove COD, BOD,SS and AOX.[14]

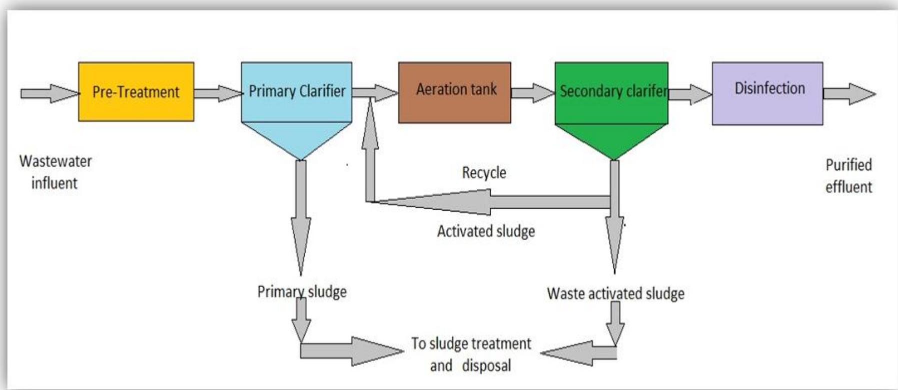


Fig: Activated sludge system

Anaerobic digestion

Anaerobic digestors are large fermentation tanks which are continuously operated under anaerobic conditions anaerobic decomposition could be used for direct treatment of wastewater, but it is economically favourable to treat the waste aerobically. Large-scale anaerobic digestors are usually used for processing of the sludge produced by primary and secondary treatments. It is also used for the treatment of industrial effluents which have very high BOD levels. The mechanisms for mechanical mixing, heating, gas collection, sludge addition and removal of stabilized sludge are incorporated into the design of large-scale anaerobic digestors. Anaerobic digestion uses a large variety of non-methanogenic, facultative anaerobic bacteria. In the first part of the process, complex organicmaterials are broken down and in the next step, methane is generated. The final products of anaerobic digestion are approximately 70% methane and 30% carbon dioxide, microbial biomass and a non-biodegradable residue. Anaerobic are more efficient than aerobics in terms of degrading chlorinated organic compounds. Anaerobic contact reactor, up-flow anaerobic sludge blanket reactor (UASB), anaerobic filter and fluidised bed reactor are mostly employed reactor types in pulp and paper mills.[15]

Tertiary treatment

Tertiary treatment involving processes such as sand filtration, reverse osmosis, adsorption and electro-dialysis is used (if necessary) to remove any residual contaminants not eliminated during the previous treatment processes. Almost 96% of COD from the paper machine, 50% of COD from pulping and 20% COD from bleaching effluents can be removed by coagulation/precipitation. Removal of colour, fuller's earth, coal ash and activated carbon has been reported by adsorption. Advanced oxidation methods such as photocatalysis, photo-oxidation, Fenton type reactions, wet oxidation, ozonation are used to achieve the destruction of chromophoric and nonchromophoric pollutants in pulp and paper mills.

Treatment of gas emissions

Volatile organic compounds produced from pulp and bleaching steps and steam are conventionally treated by physico-chemical methods such as adsorption to activated coal filters, absorption, thermal oxidation, catalytic oxidation, and condensation.

SOLID WASTE MANAGEMENT

Solid waste management deals with the production, prevention, characterisation, monitoring, treatment, handling, reuse and residual disposition of solid wastes. The concept of zero liquid discharge or ZLD emphasises on prevention of single drop of wastewater to be released into the environment. This is the reason behind using the word solid in waste management.

Waste management approach

a) Prevention: Targets at minimisation of industrial wastes at the source. Source level minimisation requires less time, technology, manpower and cost. It helps the industry from investing a huge amount of money in the waste treatment.

b) Control of environmental pollution: Stresses on treatment and disposal of wastes. Since the beginning of the environmental movement, both government regulatory agencies and the industry focused their environment protection efforts on controlling the effluent at the point where they enter into the environment. This concept is appropriately known as "End of Pipe (EOP)" treatment.[16]

While this EOP approach has to some extent been effective for protecting the environment, it has the following disadvantages:

- Transfer of pollutants from one medium to another, thereby effecting no net environmental benefits.
- Need for huge investments and recurring expenses which makes this concept highly unsustainable and at times for most the SME's this is just not feasible on account of poor profitability, space constraints etc.

Waste management usually follows a hierarchy shown in the diagram.

1. Avoidance: This is most preferable and challenges an individual and organisation to precisely calculate and purchase only what is absolutely necessary and avoid obtaining any materials that are not essential and could ultimately be wasted or passed along to the next steps in the hierarchy.

2. Reduce: The first step in managing solid waste is to reduce and strictly limit the amount of materials used. The less companies bring in, the less the company will need to haul away in the form of waste. Consumers have become more educated in ways of saving money and conserving energy thereby reducing waste. Waste reduction can often be accomplished by minimisation of consumption and purchasing fewer materials.

3. Reuse: Reusing items takes place when a product that has been used for its original purpose is later used in to accomplish the same task or to an entirely new one based on its ability to be reused. This eliminates the need to consistently reorder products and can give companies a way to be creative and find new use for existing materials. The best goods to reuse are those with no diminishing value; instead of one use plastics or disposable items, products that can be used more than once have recurring value and ultimately minimize waste.[17]

4. Recycle: Recycling acts as a last resort for companies, allowing them to send away materials, they cannot use to be made into something else. Recycling has played a major role in the creation of new and proactive environmental policies, while at the same time, creating a market fo materials that can be made into new products. Markets are created when materials such as scrap metal and higher-grade plastics are separated and sold to companies that might recycle and re-figure the materials for future use.

5. Recovery: Includes any technique or method of minimizing the input of energy to an overall system by the exchange of energy from one sub-system of the overall system with another. The energy can be in any form in either subsystem, but most energy recovery systems exchange thermal energy.

Benefits of solid waste management

- ❖ Solid waste management leads to better efficiency of production which means more output of product per unit input of raw materials. This helps in improvement of the financial performance of the industry.
- ❖ The amount of waste and emissions that need to be treated gets reduced, lowering the treatment and disposal cost.
- ❖ Waste management measures help in overcoming constraints posed by scarce or increasingly costly raw materials, chemicals, water and energy.
- ❖ Application of solid waste management assessment projects a positive environmental image of the borrower and thus improves the accessibility to finance.
- ❖ The direct effect of solid waste management is that the pollution load on the receiving environment is decreased thereby improving environmental quality.
- ❖ Minimising or eliminating the wastes makes it easier to meet existing environmental regulations and standards, and reduces the environmental impact of the industry.
- ❖ Waste management not only improves the environment outside the industry but also improves shop floor working conditions.
- ❖ Adopting waste minimisation is a proactive, positive measure and can help the concerned company build public's confidence regarding its environmental responsibility.

Barriers in solid waste management

There are several barriers to industries adopting and practising the waste management philosophy. Three broad types of obstacles to the spread of waste management within industry are: Economic, information and management attitude.[18]

- ❖ The first obstacle is the investment. Industries must be convinced that the introduction of new ways of manufacturing will really cut production costs and lend a competitive edge.
- ❖ For the firm, it is not only a matter of comparing two treatment costs but two production methods.
- ❖ Although substantial gains can be achieved through improved efficiency and better house-keeping, there comes a point where significant technological change and investment are required.
- ❖ Capital is scarce in all industries, and investments in pollution prevention must compete with other seemingly more profitable projects for funding.
- ❖ The second obstacle is the lack of information. Practical data about waste minimisation options may not be easily available.
- ❖ Industries often need local examples from their own industrial sector that demonstrate both the benefits and the feasibility of pollution prevention.
- ❖ The third and most important obstacle is management attitude. Even industries that have adopted environmental protection as a corporate goal often miss the full potential of pollution prevention by compartmentalizing responsibility: the knowledge that "someone else is responsible' is a barrier to understanding waste management problems and opportunities.

Components of landfill

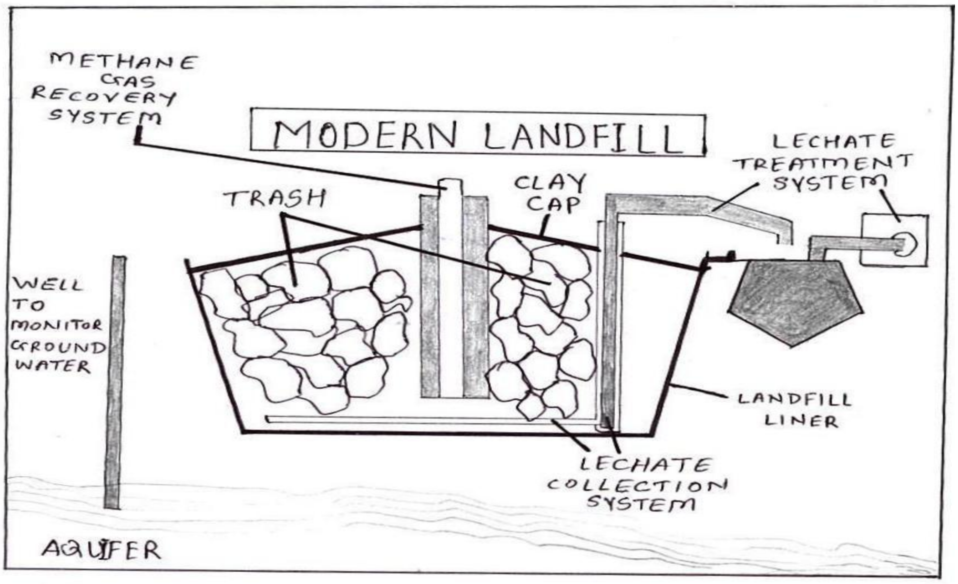
Landfill: The most widely used means of solid waste disposal is the landfill. A properly operated landfill eliminates safety hazards, fire hazards and other problems that exist in open dumping Landfill is an effective and proven method for a permanent disposal of refuses.[19]

The landfill method of solid waste disposal consists basically of following steps:

a) Depositing of refuse in planned and controlled manner
b) Compacting the refuse in thin layer to reduce its volume
c) Covering the refuse with a layer of earth/synthetic liner

The seven essential components of a landfill have been described below.

1. A **liner system** at the base and sides of the landfill which prevents migration of leachate or gas to the surrounding soil
2. A **leachate collection and control facility** which collects and extracts leachate from within and from the base of the landfill and then treats the leachate
3. A **gas collection and control facility** (optional for small landfills) which collects and extracts gas from within and from the top of the landfill and then treats it or uses it for energy recovery
4. A **final cover system** at the top of the landfill which enhances surface drainage, prevents infiltrating water and supports surface vegetation
5. A **surface water drainage system** which collects and removes all surface runoff from the landfill site
6. An **environmental monitoring system** which periodically collects and analyses air, surface water, soil-gas and ground water samples around the landfill site
7. A **closure and post-closure plan** which lists the steps that must be taken to dose and secure a landfill site once the filling operation has been completed and the activities for long-term monitoring, operation and maintenance of the completed landfill.



Landfills may have different types of sections depending on the topography of the area:

❖ **Above ground landfill (Area landfill)**

The area landfill is used when the terrain is unsuitable for the excavation of trenches in which to place the solid waste. High-groundwater conditions necessitate the use of area-type landfills. Site preparation includes the installation of a liner and leachate control system.

Cover material must be hauled in by truck or earthmoving equipment from adjacent land or from borrow-pit areas.

❖ **Below ground landfill (Trench landfill)**

The trench method of landfilling is ideally suited to areas where an adequate depth of cover material is available at the site and where the water table is not near the surface. Typically solid wastes are placed in trenches excavated in the sod. The soil excavated from the site is used for daily and final cover. The excavated trenches are lined with low-permeability liners to limit the movement of both landfill gases and leachate.

❖ **Slope landfill**

In hilly regions it is usually not possible to find flat ground for landfilling. Slope landfills and valley landfills have to be adopted In a slope landfill, waste is placed along the sides of existing hill slope. Control of inflowing water from hillside slopes is a critical factor in design of such landfills.

❖ **Valley landfill**

Depressions, low-lying areas, valleys, canyons, dry borrow pits etc. have been used for landfills. The techniques to place and compact solid wastes in such landfills vary with the geometry of the site, the characteristics of the available cover material, the hydrology and geology of the site, the type of leachate and gas control facilities to be used and the access to the site. Control of surface drainage is often a critical factor in the development of canyon/depression sites. It is recommended that the landfill section be arrived at keeping in view the topography, depth to water table and availability of daily cover material.

Advantages of landfill

- It is a relatively economical and acceptable method.
- Initial investment is low compared to other proven methods.
- The system is flexible; it can accommodate increases in the waste.
- It may result in low collection cost, as it permits continued collection of refuse. All types of refuse may be disposed of.
- The site may be located close to or in industrial areas, thus reducing the hauling cost.
- It enables the reclaiming of depression and sub-marginal lands for use and benefits of the community.
- Completed landfill areas can be used for agricultural and other purposes.

- Unsightliness, health hazards and the nuisance of open dumping can be eliminated.
- It may be quickly established.

Disadvantages of landfill

- Sometimes suitable land within economical hauling distance may not be available.
- Relatively large areas of land are required
- An adequate supply of good earth cover may not be readily accessible.
- lf not property located, seepage from landfills into streams may increase the chance for stream pollution.
- It needs careful and continuous supervision by skilled personnel
- 1f not properly done, it can deteriorate into open dumping (ordinary dumping)

Incineration

This is a type of solid waste treatment process which is basically the combustion of various organic and inorganic substances present within the waste materials. This special type of thermal treatment converts the waste into ash, flue gas and heat. Incineration reduce the solid mass of the original waste by an approximate amount of 80-85%. Garbage trucks can be used to compress the volume of waste during delivery.[20]

Various types of incineration techniques are described below.

- **Burn Pile**

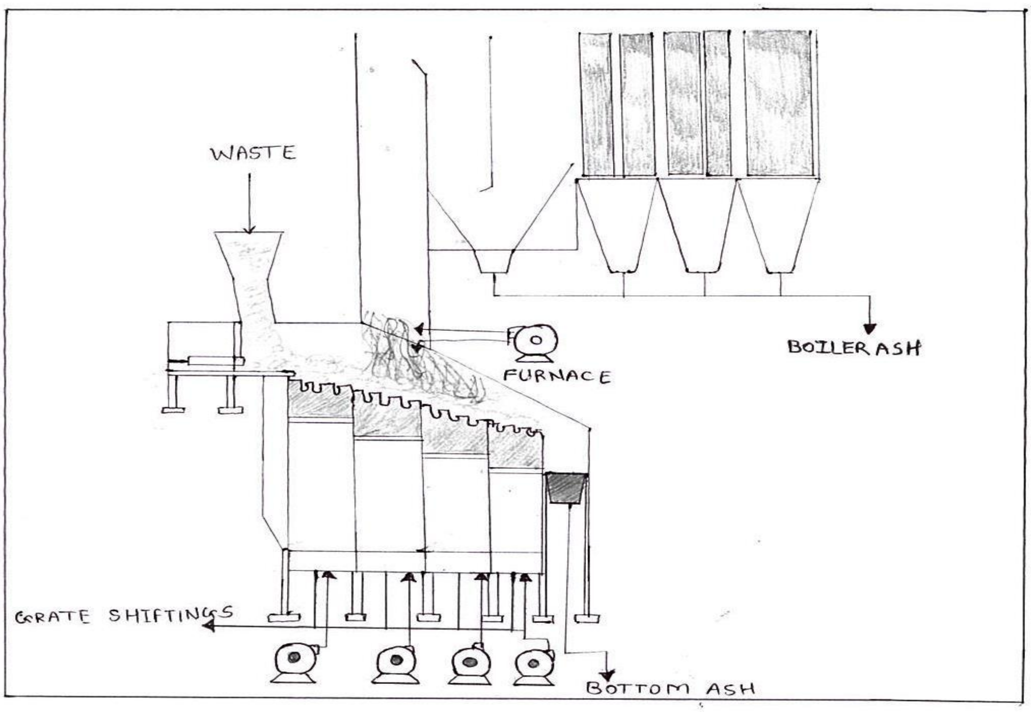
The simplest form of disposal. Piles of solid waste materials are kept on the ground and set on fire. The major disadvantage is it can produce uncontrolled fires.

- **Burn barrel**

More controlled form of waste incineration. The burning solid waste material is kept inside a metal barrel. It prevents the spread of burning material during winds and it has the additional advantage of settling down of combustibles thereby minimising the spreading.

- **Moving grate incinerator**

More efficient and complete combustion is possible by the movement of waste through the combustion chamber inside the incinerator. The waste crane allow for the introduction of the solid waste, from there it goes to the ash pit in the other end. The ash is removed through a water lock. Primary combustion air is supplied through the grate from below whereas the secondary combustion air is supplied through nozzles at a high speed. The ideal incineration plants are designed in such a way that the temperature of the flue gas reaches at least 850°C for 2 seconds for proper breakdown of toxic substances.



- **Rotary kiln**

This special type of incinerator is used for the treatment of municipal and large industry wastes. It consists of two chambers: primary and secondary. Primer chamber is the site for destructive distillation and partial combustion whereas secondary chamber is needed for gas phase combustion reactions.

Composting

Due to the ever increasing problem of landfill space constraint the recent trend is recycling by means of composting. Composting is a way of harnessing the natural process of decomposition to accelerate the decaying of solid waste. In this process the organic wastes are broken down by the microorganisms into simpler forms. The carbon present in the waste material is used as energy source by the microorganisms which in turn results in the production of the much more uniform compounds with the degradation of the nitrogen containing materials. Composting allows revitalization of soil vitality due to phosphorus depletion in the soil (2). Industrial scale composting occurs generally in the form of in-vessel composting, aerated stack pile composting etc.[21]

The most important criteria for successful composting is the temperature. Bacteria and fungi exhibits maximum decomposition in a warm, damp, well aerated environment. A large amount of initiation volume is necessary to produce the composting temperature inside the pile. Also the pile needs to be turned periodically to produce aeration.

- ✓ **In vessel composting**

In this method the composting materials are kept within a building, container or a vessel. Air flow and temperature can be controlled inside the vessel. Aeration is provided via buried tubes whereas temperature and moisture are maintained using probes. The technique is mostly used for the municipal wastes.

- ✓ **Aerated stack pile**

Here the organic material is biodegraded without any physical change during primary composting that is why it is known as static. The materials are kept over a perforated pipe to allow the aeration. These systems offer a major advantage of process control for rapid biodegradation. Due to the high cost associated, it is used mainly in large scale composting facilities.

Current research

Current generation of nanotechnologies in modern paper mill, silica nanoparticles nowadays are becoming centre for attraction for all the paper and pulp industries; as a result of these nanoparticles there is high-performance retention/ drainage providing better formation as well as silica nanoparticles yields a favorable open sheet structure for select bag application. New nano-sizing technologies improves surface sizing. These nanocoatings/barriers provide controllable inner environment for packaging CO2, N2, H2O, O2. These also provide defense system for bacterial and fungal growth i.e.; active and passive and homeland security such as tamper proof, counterfeit resistance and smart packing with advanced inventory control.

Great benefit can be delivered in the form of small molecule to paper and pulp industries by catalytic activation of hydrogen peroxide. TAML® catalysts are one-time-use small molecule catalysts that can improve peroxide bleaching and also treats effluents from any chlorine-based (D, C, H) bleaching that is contaminated with “color” and chlorinated lignin fragments called collectively “AOX” for “absorbable organic halogen’. AOX is chlorinated material than can be captured on activated carbon.[22]

Species such as Pseudomonas, Bacillus, Pannonibacter, and Ochrobacterum were found capable of reducing COD of wastewater released from paper and pulp industry up to 85%–86.5% in case of back water and 65-66% in case of back water : black liquor (60 : 40), respectively, after acclimatization under optimized conditions (pH 6.8, temperature 35°C, and shaking 200 rpm) when the wastewater was supplemented with nitrogen and phosphorus as trace elements, as there is huge amount of pollutants released from the industries and the environment s getting affected by it. Lack of infrastructure, technical manpower and research and development facilities restricts these mills to recover these chemicals. Therefore, the chemical oxygen demand (COD) of the emanating stream is quite high. For solving the above problem, these four bacteria were isolated from the premises of agro-based pulp and paper mill which were identified.

Greenhouse gas emission is a major problem from conventional solid waste management approaches. Whereas development and introduction of a new technology known as Integrated Solid Waste Management (ISWM) can be a practical solution for diminishing this GHG emissions and thereby keeping the environment clean.

Web-GIS based systems are the on-going topics of research to optimise waste collection through separation. The preliminary study indicated an efficiency of 80%. A Web-GIS based system contains frequency of collection as an adaptive parameter. Producer responsibility can be seen as different kinds of users and pathways to be included in the system.[23]

Development of Interval Valued Fuzzy Stochastic Programming (IVSP) is in progress that can tackle multiple uncertainties as well as possibility and probabilistic distributions. This can help waste managers to identify desired allocation scheme for the waste flow and also the capacity expansion plans according to the conditions and preferences.

Hydrothermal carbonization (HTC) is a rapid thermal conversion process that is a possible way of managing solid waste streams which also minimises GHG production. This method converts biomass to a carbonaceous residue referred as hydrocar.

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