Pollution Control in Meat Industry

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Abstract: Meat industry generates various wastes such as effluent, emissions and solid wastes that pose environmental and health problems. The effluent released from the meat industries finds its way into the natural water resources and degrade the water quality. The solid wastes of meat industry create a public nuisance by way of foul smell if it is not handled properly. The effluents, as well as solid wastes of meat industries, are possible sources of pathogens that are hazardous to human health. Waste minimization, segregation of wastes and treatment, processing of wastes to make possible recoveries of by-products and the final disposal are the basic steps for containment of pollution from the meat industry. The effluent treatment technologies include primary treatment, secondary treatment and tertiary treatment. Composting, biomethanation, rendering, incineration and burial are the processes for disposing of the solid wastes generated by meat industries. Appropriate treatment process is selected considering the level of pollution, mode of disposal and the environmental standards. The treatment and processing of meat industry wastes minimize the pollution problems and also give scope for the recovery of by-products such as bone and meat meal, tallow, methane and manure that have commercial values. The meat industries also generate odours that are required to be contained using suitable control devices. The paper seeks to give an overview of the pollution control technologies currently in use for the treatment of effluents and solid wastes, and possible recovery of by-products.

Keywords: Meat industry, slaughter house, abattoir, pollution control, waste management, treatment technology.

1. INTRODUCTION

Meat industry converts healthy animals into meat fit for consumption and hence, it answers one of the basic requirements of human beings i.e. food. Besides producing meat, the industry supports several other sectors such as tanneries, bone mills, pharmaceuticals, fertilizer, gelatin, glue and pet feed manufacturing units, which use the by-products and wastes of meat industry as raw materials. The meat is supplied from the meat industry as flesh or processed meat. Live stocks available for the meat industry are mainly cattle, sheep, goats, pigs and poultry. In some parts of the world, horse, dear and rabbit are also meat animals. The meat industries range from those processing only a few animals in a day to several thousand animals with modern facilities. The meat industries can be classified based on the type of animals processed such as cattle meat industry, goat/sheep meat industry, etc. The second criterion of classification is based on the operations performed like slaughterhouse and meat processing (frozen or processed meat) industry. In case, an industry carries out all the operations starting from the killing of animals to the finished meat products, the unit is generally known as integrated meat industry. The production capacity is another consideration for classification such as small, medium and large meat industries. It is noticed that there is no hard and fast rule to classify the meat industries. Depending on the purpose and convenience, the agencies use appropriate terminology and classification. Fig. (1) shows the classification of the meat industries.

Like any industrial activities, the meat sector is responsible for all kinds of pollution generation. The effluent released from the industries has the
potential to pollute the natural water resources [1-3]. The solid wastes create a public nuisance by way of foul smell if it is not handled properly. The effluents, as well as solid wastes, are also possible sources of pathogens that are hazardous to human health [4, 5]. Use of antibiotics in the rearing of animals for food and the spread of Antibiotic Resistance (ABR) posed a new threat to human health. A study by Bhushan et al. [6] highlighted the rampant use of antibiotics in the poultry industry. The paper seeks to give an overview of the pollution control technologies currently in use for the treatment of effluents and solid wastes, and possible recovery of by-products.

2. PRODUCTION PROCESS

After arrival in the industry premises, the animals are held in lairage to allow them to recover from the stress of journey, which improves the quality of meat by allowing adrenaline and glyco- gen level to reach the normal level. The animals are taken in the stunning pan one at a time. The large animals are stunned with captive bolt pistol or rifle bullet. Sheep, goats and pigs are normally stunned with the help of electric stunner. Then, the animal is slaughtered and the body is hoisted with hind legs to ensure complete bleeding. The blood is collected for further processing to make blood meal or for pharmaceutical use. After bleeding, the animal body is dressed that includes removal of horns, legs, head trimming, demasking, flaying of abdomen and chest, and removal of hide or skin. The process of separating edible and inedible offal is termed as evisceration. During evisceration, the edible offal is cleaned with water and collected, and the remaining inedible offal is disposed of as a solid waste or processed to recover by-products. The dressing and evisceration are usually carried out in hung position supported by overhead rail that facilitates easy movement of the animal body to perform the operations with the help of equipment. After dressing, evisceration and removal of edible and inedible offal from the animal body, the reaming portion is called carcass, which is washed with clean water. The carcass so produced is utilized for human consumption with or without further processing.

The carcasses of animals are further processed to produce either frozen meat or processed meat products. The washed carcasses after dressing and evisceration are initially kept in chilling halls for 24 hours, which are maintained at 4°C temperature. The carcasses are then taken to processing halls where deboning is performed. The deboned meat is cut into pieces as per the requirement and packed in polythene bags. Poly-bagged meat is further frozen to -40°C temperature using blast freezing or plate freezing process. The frozen meat is packed in corrugated boxes and then kept in cold storage at -18°C temperature for 72 hours before it is dispatched. The production of processed meat includes grinding, curing, pickling, smoking, cooking and canning. The canned products are generally ready to eat.

The production process of the meat industries is delineated in Fig. (2). Sources of effluents, solid wastes, by-products and odours are also depicted in the figure.

In the case of pig slaughtering also, the basic unit operations viz. slaughtering and bleeding, dressing and evisceration are identical to that of cattle, goat and sheep slaughtering. The only additional operations are scalding and dehairing. Also, the skin is not removed but retained with the body to form part of the meat. For scalding, the body is dipped into hot water (65°C) for 3 to 6 minutes to relax the muscle so as to make the dehairing operation easier. Dehairing is done with the help of dehairing machine. Final dehairing is accomplished with a burner, which is referred to as singeing operation. After singeing, the carcass is passed through a black scraping machine (rind operation) to polish the skin and remove singed hair and other debris.
Fig. (2). General process flow diagram of meat industry.
Poultry or birds are brought in poultry processing industry in crates and modules. The birds from crate and modules are then put on to the killing line. Stunning system comprises of a water bath with one electrode and a bar that comes in contact with shackles used to hang the birds upside down forms the other electrode. The bird gets stunned as soon as its head comes in contact with water. After stunning, the bird is allowed to bleed for a few minutes and then immersed in a scalding tank filled with warm water, where the temperature is maintained at 50 to 58ºC. Feathers are removed immediately after scalding with the help of a series of online plucking machines. For defeathering of ducks, the body is dipped in a bath of hot wax and then is cooled with water that hardens the wax. The hardened wax together with feathers is removed with a machine or by hand. Finally, the defeathered chickens are washed with clean water and moved for dressing and evisceration.

3. POLLUTION GENERATION

3.1. Effluents

Utmost all the operations carried out by the meat industry are water intensive and cause voluminous effluent generation. The animals and the vehicles used for transporting the animals are regularly washed. Lairage area is also periodically washed. The slaughtering of animals, bleeding, dressing and evisceration are major sources of effluent generation. In addition, the by-products and wastes handling, storage and preservation operations are a source of water pollution. The machinery, equipment and floors of process halls for products, by-products and wastes are washed and disinfected from time to time. All these activities generate a considerable quantity of wastewater. The wastewater contains pollutants such as blood, pouch (stomach and intestine) contents, dung, urine, meat trimmings, hairs, feathers, fat, disinfectants etc.

All the contaminants increase the pollution potential of effluent. The meat industry wastewater is biodegradable in nature and hence, characterized mainly by the measurements of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS).

Typical characteristics of the meat industry are shown in Table 1 [7]. It can be noticed that the effluent contains BOD of 1200-4000 mg/L, which is mainly contributed by blood that has a very high BOD. Hence, even a small quantity of blood has the potential to raise the BOD level in the effluent. High level of TSS (1500-4500 mg/L) is mainly due to the mixing of stomach and intestine contents in effluent streams during the evisceration process. The effluent characteristics and quantity may vary from industry to industry depending upon the type of animal processed, scale of production, operations performed, effectiveness in the recovery of by-products and the cleaning practices.

Table 1. Typical characteristics of meat processing industry effluent [7].

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>pH</td>
<td>7.6-8.2</td>
</tr>
<tr>
<td>2.</td>
<td>Total suspended solids, mg/L</td>
<td>1500-4500</td>
</tr>
<tr>
<td>3.</td>
<td>Biochemical oxygen demand, mg/L</td>
<td>1200-4000</td>
</tr>
<tr>
<td>4.</td>
<td>Chemical oxygen demand, mg/L</td>
<td>3000-7000</td>
</tr>
</tbody>
</table>

3.2. Solid Wastes and By-Products

The solid waste quantity generated from the cattle, goat, sheep and pig processing industries is presented in Table 2 [8]. It can be noticed that pig is very efficient animal as far as meat yield is concerned. The solid waste quantity may vary due to the effectiveness of facility available at the industry for recovery of by-products. The unrecovered wastes are generally disposed of as landfill. In many industries, fodder and dung are collected separately for composting. The industries with manual operation collect stomach/intestine contents also together with the fodder and dung for making compost or biogas.

3.3. Odours

All the wastes and by-products of the meat industry are highly perishable and hence, cause odour problems due to putrefaction. Blood, inedible offal and by-product storage areas are the sources of fugitive odours. In addition, rendering, cooking, smoking and curing operations cause foul smell due to malodorous substances present in the exhaust gases. Chilling and freezing plants are also sources of refrigerant gases.
4. POLLUTION CONTROL SCHEMES

4.1. Effluent Treatment

The effluent generated from the meat industry is mostly treated using primary, secondary and the tertiary treatment methods. The first step in the water pollution control is to minimize the pollution load in the effluent that can be affected by preventing the by-product and waste materials from entering into the effluent streams. Segregation of highly polluting effluent stream from the low polluting stream followed by treatment of each effluent stream separately, gives better performance of the effluent treatment system. The second step in the effluent treatment is to collect and remove the floating and suspended matters such as fodder, meat pieces, hairs, feathers etc. through screening. The meat industry effluent contains fat/oil that is removed using an oil and grease trap, a tank wherein effluent is held for a few minutes and let out from the bottom. The fat and oil float on the surface of effluent, which can be skimmed off. The next step in effluent treatment is to equalize the effluent streams that are discharged at different intervals from different stages of production. The equalization ensures uniform characteristics in terms of pollution load, pH and the temperature. The effluent is further treated in the primary treatment unit including addition of the coagulants such as lime, alum and polyelectrolyte followed by flocculator and clarifier or settling tank. Alternatively, dissolved air floatation is also employed.

The main objective of the primary treatment is to remove total suspended solids. While achieving this objective, the primary treatment also minimizes Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) contents. Next step in effluent treatment is the secondary treatment that is either aerobic or anaerobic biological treatment process. The secondary treated effluent is further treated with sand filter, activated carbon filter, chlorination, ozonation, membrane filtration etc. to improve the effluent quality. The advance oxidation and electrochemical coagulation process of effluent treatment have been explored for the treatment of effluents.

The treated effluents confirming to the prescribed standard can be discharged into inland surface water or can be reused for horticulture, gardening and cleaning of lairage etc. Depending upon the pollution load, effluent discharge standards and mode of disposal, one or more than one method is applied for the treatment of the effluent.

4.2. Solid Wastes and By-products Management

Every by-product or waste of meat industry can be utilized. However, various circumstances do not always permit the recovery of by-products from the wastes. Inadequate quantity of materials, lack of market, cost of processing etc. sometimes hinder the process of recovery. In such instances, the materials simply form a part of waste lot for which different methods of processing and disposal have to be considered. The solid waste of meat industries can be broadly classified into two categories i.e. vegetable matter and animal matter. These waste streams should be segregated so that the wastes can be properly treated. For the meat industry wastes, composting, biomethanation, burial and rendering systems are applied. Selection of appropriate method, however, depends mainly on type of wastes and its quantity. Incineration is also an option for treatment of slaughter house waste.

4.3. Odours

All the wastes and by-products of meat industry are highly perishable and hence, cause odour problems due to putrefaction. Blood, inedible offal and by-product storage areas are the sources of fugitive
odours. In addition, rendering, cooking, smoking and curing operations cause foul smell due to malodorous substances present in the exhaust gases. The exhaust gases are purified with the help of biofilters, wet scrubber and activated carbon filter.

4.4. Antibiotic Resistance

Uses of antibiotics in rearing of animals for food and the spread of Antibiotic Resistance (ABR) have attracted attention of researchers in recent past. The spread of antibiotic resistant bacteria posed a new threat to the human health. Many countries have taken up mitigation programme, and WHO and FAO is supporting the countries in their programme [6]. Containment of spread of ABR requires destroying the resistant bacteria in meat industry wastes before disposing the wastes.

The pollution control processes and technologies relevant to the meat industry are given in Table 3.

5. OVERVIEW OF FEW TREATMENT TECHNOLOGIES

5.1. Effluent Treatment

5.1.1. Screening

There is practice to use both coarse bar screening (>6 mm) and fine screen (6-1.5 mm) with self cleaning system. A very fine screen (0.2-1.5 mm) can also be installed after the course screen to further purify the effluent from suspended matter. There are mainly three types of screens namely, inclined self cleaning, rotary drum and vibrating screens. These screens are capable to remove the suspended impurities to a large extent (Fig. 3).

![Fig (3). Rotary screen (Diameter 1 m, pore size 2 mm and rpm 90).](image)

5.1.2. Oil Grease Trap

Oil and grease trap is provided to remove the fat, oil and greasy material. This is effected by slowing down the speed of effluent in a tank. The oil and grease trap receives effluent and allows its escaping from the bottom of tank. The oil and grease being lighter than water tend to float at the surface of effluent and the same is removed manually or through a mechanized scrapper. The oil and grease removed can be processed in rendering. The removal of oil and grease from the effluent increases the performance of the subsequent effluent treatment units.

5.1.3. Dissolved Air Floation

The fat and oil content, and the suspended matter are removed from effluent in a air flotation system by adding metal salts such as ferrous sulphate, ferric chloride, aluminum chloride and polymers

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**Table 3. Pollution control processes and technologies for meat industries.**

<table>
<thead>
<tr>
<th>Wastes</th>
<th>Type of Treatment</th>
<th>Treatment Processes and Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effluent</td>
<td>Preliminary treatment</td>
<td>Screening, Oil and grease trap.</td>
</tr>
<tr>
<td></td>
<td>Primary treatment</td>
<td>Equalization, Dissolved air floatation, Sedimentation, Tube settler, Chemical treatment, Electrochemical coagulation.</td>
</tr>
<tr>
<td></td>
<td>Secondary treatment (Bio-logical treatment)</td>
<td>Anaerobic treatment (Anaerobic reactor, Packed bed reactor, Anaerobic lagoon; Aerobic treatment (Activated sludge process, Trickling filter, Rotating biological contactor, Aerobic lagoon).</td>
</tr>
<tr>
<td></td>
<td>Tertiary treatment</td>
<td>Pressure sand filter, Adsorption, Ozonation, Chlorination, Advance oxidation, Polishing pond, Membrane filtration.</td>
</tr>
<tr>
<td>Solid wastes and by-products</td>
<td>Processing, utilisation and disposal</td>
<td>Rendering, Composting, High rate biomethanation, Burial, Incineration.</td>
</tr>
<tr>
<td>Odours</td>
<td>Treatment</td>
<td>Biofilter, Wet scrubber, Activated carbon adsorption.</td>
</tr>
</tbody>
</table>
are used for precipitation and flocculation. Floatation of particles is induced by micro-bubbles which are produced usually by dissolved air. In this process, the bubbles attached to the particles and the buoyancy force acting on the bubbles is sufficient enough to cause them to rise to the effluent surface. The particles that have higher density than liquid are separated from liquid. Separation of particles that have lower density such as fat and oil can be enhanced with the floatation system. The particles that have been floated along with the micro-bubbles to the surface of effluent, are removed with the help of scrapper mounted on conveyor. The process is beneficial as the retention time is less and very fine particles can be removed. However, it is more complex than the gravity settling clarifiers (Fig. 4).

5.1.5. Biological Treatment

**Trickling Filter:** Trickling filters comprises of a highly permeable bed that supports growth of microorganisms. The effluent is percolated or trickled down through a bed of filter media. The organic contaminants in the effluent are degraded by the microorganisms attached with permeable bed and form a slime layer on the surface of filter media. The filter media normally consists of rock or plastic packaging with very high surface area. As the microorganisms grow, the thickness of the slime layer increases and after some period, the effluent washes away the slime layer so formed. Then, a new slime layer starts forming. This phenomenon is called sloughing. The effluent leaving the trickling filter has low organic impurity. The trickling filters are simple to operate and more suitable where there is land constrains. However, the treated effluent may require additional treatment to meet more stringent effluent discharge standards. Moreover, the incidence of clogging is relatively high. Operation of trickling filter may lead to aerosol problem and create public nuisance by way of foul smell.

**Rotating Biological Contactor:** The rotating biological contactor consists of a series of closely packed discs made of polystyrene or polyvinyl chloride. The discs are partially submerged in the effluent to be treated and kept rotating. Rotation keeps the discs to come in contact with organic contaminants of effluent and then in contact with air to meet the oxygen requirement of microorganisms developed on disc’s surface. During the operation, a slime layer of degraded organic impurity is formed on the surface of discs. The biological contactors operate on low food to microorganism ratio, which facilitate microorganisms to withstand hydraulic and organic surges more effectively. The operation of the rotating biological reactor needs uninterrupted continuous power supply.

**Activated Sludge Process:** In this process, biological treatment of effluent is provided in aeration tank, wherein microorganisms are always kept in suspension while supplying the air though mechanical surface aerators or diffused aeration (Fig. 5). There is practice to use pure oxygen as an alternative to air for enhanced performance of the activated sludge process. A required balance of
food (usually BOD of effluent) and oxygen is maintained for proper growth of microorganisms in the aeration tank. The contents of aeration tank are referred to as Mixed Liquor Suspended Solids (MLSS). The organic substances in effluent is converted into oxidized products and sludge that are removed from liquid phase in a clarifier or settling unit. A portion of sludge from the clarifier is recycled back into the aeration tank to make proper balance of mixed liquor suspended solids. The process is highly sensitive to pH, temperature and toxic constituents such as heavy metal. Due to high operation efficiency, it is possible to achieve effluent discharge norms.

**Fig. (5).** Aeration tank with diffused air aeration.

**Anaerobic Digester:** The anaerobic process involves decomposition of organic and inorganic impurities in the absence of molecular oxygen. The major application of this process has been to treat the effluents bearing high organic load and stabilization of the sludge generated from the effluent treatment plants. In anaerobic digester, the organic matter present in effluent or sludge is converted to varieties of end products including methane. An Upflow Anaerobic Sludge Blanket (UASB) reactor produces methane gas to the tune of 0.356 m³/kg COD at a loading rate of 3.5 kg COD/m³.day, which can be used as a fuel [9] (Fig. 6). A well stabilized sludge is also generated that can be used as manure or soil conditioner. However, the anaerobic digester gives low performance as far as treated effluent quality is concerned.

**Fig. (6).** UASB digester and gas holder.

**Packed Bed Reactor:** The anaerobic packed bed reactor is a container, which is packed with a medium for sustenance and growth of microorganisms. The effluent is introduced from the bottom of container through a pipe-network for proper distribution across the bottom. Packed bed reactors generally give poor quality of effluent and hence, it is used as a pretreatment. The treated effluent is further treated in aerobic process to get the desired effluent quality. Anaerobic packed bed reactors produce biogas that can be used as a fuel.

**5.1.6. Pressure Sand Filter**

In pressure sand filter, effluent flows downwards through the sand bed. The suspended matter is retained over the top layer of the bed and interstice between sand particles. As the filtration proceeds, the effluent flow rate decreases due to the reduction in porosity of sand bed, which intern increase head loss. Cleaning of sand bed is effected by backwash water. To enhance the cleaning operation, sand bed is subjected to air agitation through underdrain system. This process is effective for the treatment of turbid effluent, but it is incapable of removing the bacterial contaminants.

**5.1.7. Activated Carbon Adsorption**

Activated carbon (granules or powder) is used for the treatment of effluent as well as water. The treatment system consists of a cylindrical vessel in which a fixed bed of activated carbon granules is contained. The effluent flows downward through the bed under gravity. In the process, contaminants
present in the effluent come in contact with active sites available on the carbon surface and get adsorbed. The treated effluent is taken out from the bottom of the vessel. The activated carbon (powder form) is usually mixed with effluent and agitated well to facilitate the adsorption of contaminants. Once the adsorption is completed, the powdered activated carbon is separated from the effluent stream with the help of suitable filter. In the adsorption process, the activated carbon becomes less effective or ineffective as the adsorption process continues. In such case, the activated carbon has to be replaced or regenerated. The activated carbon system removes wide verities of organic pollutants. It is very flexible, easy to operate and allows quick start up and shut down as may be needed. There is no generation of sludge from the adsorption process (Fig. 7).

5.1.8. Ultrafiltration

This process is similar to reverse osmosis. The reverse osmosis membranes retain all solutes including salts, while ultrafiltration membranes retain only macro molecules and suspended solids. Thus, salts and low molecular weight organic pollutants cannot be separated by ultrafiltration membrane. The ultrafiltration membranes is prepared from cellulose acetate, polyelectrolyte complexes, nylon and inert polymers. The ultrafiltration process is effective for the removal of all types of impurities including colloids and protein. However, the disposal of the reject stream of the filtration is a problem. Further, fouling and replacement of the filter media make the process expensive (Fig. 8).

5.1.9. Oxidation

Ozonation and chlorination are most commonly used oxidation processes that are required to disinfest the effluent and kill germs. Chlorine is available as compressed elemental gas, sodium hypochlorite solution or solid calcium hypochlorite [10]. Hydrogen peroxide has been widely used in the bleaching operations. The hydrogen peroxide along with an iron catalyst, known as Fenton’s reagent, becomes a strong oxidizing agent for use in the effluent treatment. As available in literature, the advanced oxidation methods for effluent treatment include combination of the oxidants such as UV-H2O2, UV-ozone, H2O2-ozone and Fe2+-H2O2. The oxidation processes are effective in the effluent treatment. These methods are costly.

Selection of appropriate effluent treatment processes depends on effluent quantity, pollution load, land available and the effluent disposal standards. The performance of effluent treatment plant installed in a typical meat industry is given in Table 4 [11]. The effluent treatment plant consists of the following units: Oil and grease trap, Equalization tank (13.8 m x 7.5 m x 5 m), Rotary screen (Diameter 1 m, pore size 2 mm, rotation 90 rpm), Coagulant dosing tank, Tube settler, Dissolved air flotation (Air pressure 40 lb/PSI), Aeration tank I (Volume 1468 m³, HRT 48 hours), Craftier I (Diameter 5 m x 3 m depth, HRT 1.3 hours), Aeration tank II (Volume 1638 m³, HRT 48 hours, loading rate 0.6 kg BOD/m³.day, Mean cell retention time 10 day, F/M ratio 0.4), Craftier II (Diameter 5 m
x3 m depth, HRT 1.3 hours), Effluent sump (4.8 m x 4.8 m x 3 m), Pressure sand filter (Diameter 0.8m, Height 2m), Activated carbon filter (Diameter 0.8 m, Height 2 m), Effluent flow meter and sludge drying beds. It can be noticed that the effluent is neutral with pH of 7.01 to 7.33. Raw effluent sample indicated TSS of 3846 mg/L, TDS of 7722 mg/L, BOD of 3575 mg/L and COD of 8097 mg/L. High concentrations of the polluting parameters are due to the fact that the meat industry effluent contains blood, bits of flesh, manure, dirt and viscera.

After the primary and secondary treatments, the effluent attains TSS of 95 mg/L, TDS of 5612 mg/L and COD of 111 mg/L. High concentrations of the polluting parameters are due to the fact that the meat industry effluent contains blood, bits of flesh, manure, dirt and viscera.

The tertiary level treatment produces effluent with TSS of 53 mg/L, TDS of 5892 mg/L, BOD of 19 mg/L and COD of 74 mg/L. The overall efficiency of the entire treatment plant was observed as 98.62% in terms of TSS and 99.08% in terms of COD removals. It can be observed from the analysis results that TDS level in effluent does not reduce significantly. This may be due to the salt content, which is contributed by effluent from hiding preservation operation.

5.2. Solid Waste Management

5.2.1. Composting

Practically, all the wastes from the meat industry i.e. vegetable matter and animal matter can be used for compost making. The agriculture residue and dung from the lairage, ruminal and intestinal contents, blood, meat cuttings, floor sweepings, hair, feathers and hide trimmings can be stabilized by the composting process. It is suggested that alternate layers of vegetable wastes and animal wastes should be laid to make a compost heap of 4 to 5 feet height. Proper aeration is required throughout the process in order to achieve optimum conditions of moisture and oxygen for bacteria.

5.2.2. High Rate Biomethanation

The high rate biomethanation plants are designed to cater to effluent stream with high concentration of pollutants, and shredded animal matters. The success of a biomethanation plant depends on several factors, such as the quality of the raw materials, temperature, ratio of water to solids, and also on the type of bacteria present. Nowadays, advanced biomethanation (high rate biomethanation) plants are increasingly being used (Fig. 9).
5.2.3. Rendering

Wet Rendering: The name wet rendering is applied where the raw material is processed with added water or condensate derived from steam. The wet-rendering tank is usually a vertical-cylindrical boiler, having a cone-shaped bottom. At the top of the tank there is a manhole through which raw material is loaded, and also a valve through which obnoxious gases escape without reducing the pressure. Steam is injected from the bottom of the tank.

After the raw material is loaded, the manhole is tightly closed and steam is let into the mass. After cooking is completed, the contents of the tank are allowed to settle. The water and fat can be drawn off through the side cocks. The solid waste is removed by opening gate valve.

Dry Rendering: This process is intended to remove unwanted moisture in animal matter but without the loss of solid nutrient in cooker consisting of steam jacket and agitators. The material is loaded in the cooker and does not come in direct contact with steam that is injected in jackets. Due to heat transfer from steam jacket to the material, evaporation of moisture takes place that builds up pressure in the cooker. Temperature, pressure and agitator ruptures fat cells. After desired level of moisture is achieved, the hot mass is removed from the cooker and the fat from the mass is removed with the use of hydraulic press or centrifugal process (Fig. 10).

5.2.4. Incineration

Incineration can be used for treatment of many wastes. Unlike previous methods, incineration provides no by-products but recovery of heat is possible. The incineration is a quick process and does not require long residence time as in case of other methods. Proper temperature control, mixing and turbulence are necessary for effective combustion. Capital cost and recurring expenses of incinerator are high. By using heat recovery system, the cost of operation can be reduced through use or sale of energy. The drawback associated with the incineration technique is that all the potential by-products are destroyed.

5.3. Odour Control

In general, the fugitive odours can be contained by maintaining a minimum standard of sanitation and hygiene together with preservation of perishable materials. Odour control device is installed for containment of high intensity emission of odours such as exhaust gases of rendering operation.

5.3.1. Biofilters

Biofilters are used to remove the malodorous substances present in the exhaust gases or air from rendering plant or other operations. It consists of a porous bed with a distribution system to apply the exhaust gases uniformly across the bed. The bottom of the biofilter consists of stones, over which a layer of pebbles is laid. The pebbles are covered
with a layer of porous biofilter media with large surface area that supports growth of the microorganisms. Malodorous substances present in the air are consumed by the microorganisms for their sustenance and growth. Usually rice husk, bark, heather or similar agriculture produce/wastes are used as biofilter media. Broken pellates, light expanded clay aggregates, peat and clay of defined particle size can also serve the purpose of filter media. The odourous gases let out from the rendering plant or other sources is first cooled to the required temperature and then cleaned to separate suspended impurities. The cooled and purified gases or odorous air stream is passed through bottom of the biofilter with a care to distribute uniformly across the filter bed. The gases moves upward through layers of stones, pebbles and then comes in contact with the bed of filter media. There is need to maintain a required contact time so that the microorganisms present in the biofilter media can consume the malodorous substances present in the gases for energy and growth. The biofilter media is always kept moist by sprinkling water over it or alternatively, the gases are humidified prior to its feed in the biofilter.

The efficiency of the biofilter can be optimized by maintaining proper gas flow rate or gas residence time, moisture content, pH, temperature, oxygen requirement and nutrients. The residence time depends on pollutants present in gases and their concentration. The residence time of 30 seconds for low odour gases can be sufficient to treat the low odour intensity gases, which can increase up to 60 seconds for high odour intensity gases [13] (Fig. 11).

5.3.2. Wet Scrubber

Wet scrubbers are effective pollution control devices for purifying the odorous substances present in the exhaust streams. The odorous gas stream is introduced from the bottom of the

Fig. (10). Rendering: (a) Rendering plant and (b) Bone and meat meal produced by the rendering plant.
scrubbing column wherein a scrubbing liquid usually, water or water and chemical are sprinkled from the top. The malodorous substances present in the gases are collected in the scrubbing liquid. The scrubbing liquid is recycled. During this process, the liquid gets saturated over the time and hence, it is replaced or regenerated by adding fresh chemicals (Fig. 12).

5.3.3. Activated Carbon Adsorption

The odorous gases can be treated using activated carbon that has a very large surface area in the form of micro-pores. The odor molecules are retained in the micropores of activated carbon that minimize odour problem. As the pores get filled up over the time, the activated carbon needs to be replaced or regenerated to attain the desired efficiency.

CONCLUSION

Meat industry converts healthy animals into meat fit for human consumption. The operation of the meat industry generates voluminous effluent and solid wastes. The pollution control techniques available for meat industry effluent include primary, secondary and the tertiary level treatments. Several technologies are available in each treatment level including dissolved air floatation, coagulation and flocculation, anaerobic and aerobic biological processes, pressure sand filtration, activated carbon adsorption and oxidation. Inedible offal (other than carcass) is processed to make re-
covery of by-products using rendering and other processes. All the by-products or wastes of meat industry can be utilized. However, various circumstances do not always permit the by-product recovery from the wastes. The unrecovered materials including dung, stomach and intestine contents are treated using composting and biogamethanation that convert the wastes into methane and manure. All the wastes of the meat industry are highly perishable and cause odour problems, if not handled properly. The malodorous gases are treated using biofilters, activated carbon adsorption and wet scrubber. It is to be noted that all the wastes generated by the meat industries are bio-degradable in nature and hence, can be easily stabilized using appropriate technologies. Use of antibiotics in the rearing of animals for food and the spread of antibiotic resistance posed a new threat to the human health that underlines the need for destroying the resistant bacteria in meat industry wastes before disposal of the wastes in the environment.

LIST OF ABBREVIATIONS

ABR = Antibiotic Resistance
BOD = Biochemical Oxygen Demand, mg/L
COD = Chemical Oxygen Demand, mg/L
F/M = Food to Mass ratio
HRT = Hydraulic Retention Time, h
MLSS = Mixed Liquor Suspended Solids, mg/L
TDS = Total Dissolved Solids, mg/L
TLWK = Ton of Live Weight Killed, Ton
TSS = Total Suspended Solids, mg/L
UASB = Upload Anaerobic Sludge Blanket
UV = Ultraviolet

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

REFERENCES