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A Review on Abattoir Wastewater Treatment for Environmental Health Improvement

MT Adamu[1]* and M Dahiru[2]

[1]Department of Microbiology, Faculty of Science,
Gombe State University, Nigeria.
[2]Department of Biological Science, Faculty of Science, Federal University,
Kashere, Gombe, Nigeria

*Corresponding author:
Dr. Adamu Muhammed Tukur,
Department of Microbiology,
Gombe State University,
PMB 127, Tudun Wada,
Gombe,
Nigeria.
Email: microtukur@gmail.com

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Abstract

Impact of indiscriminate discharge of abattoir wastewater has been a major cause of concern globally due to its negative effect on public and environmental health. Lack of wastewater treatment plants and guidelines for proper disposal in many developing countries generates other numerous ecological problems to the affected countries. Its role as a nutrient-provider for pathogenic microorganisms was highlighted by many researchers. Treatment of abattoir wastewater remains the main reliable and efficient means of reducing environmental pollution it may consequently cause. Environmental pollutants released through wastewater by abattoirs may be complicated due changes brought about by additional substance used during animal processing. Several methods adopted by abattoirs were reported to be effective. However, the need for improvement in line with environmentally friendly guidelines is recommended.

INTRODUCTION

Agro-allied and food industries frequently discharge considerable amounts of wastes in countries where sufficient sewage disposal facilities are inadequate, such wastes pose environmental and public health obstacles. The slaughtering process in the meat industry is the major contributor to liquid waste [1]. Animal waste has been defined as "carcasses or parts of animals, including products of animal origin not intended for direct human consumption" [2]. Indiscriminate discharge of waste by many slaughterhouses has resulted in serious environmental problems [3-5]. Due to legal restrictions, increase in treatment costs and environmentally conscious consumers, the treatment of wastes and some solid residues and particularly, effluents from wastewater treatment facilities emerged as a serious issue concern in meat industry [6].

It was estimated that the waste sourced from farmlands in Denmark amounted to 40–50x10^6 metric tons of solid and liquid manure. Besides, the water used in slaughterhouses and dairy plants amounts to about 40x10^6 m^3 per year, equivalent to the amount of water used by 500,000 people. However, the waste effluents discharged by the industries were so grossly polluted with biological contaminants and chemicals that it required a high purifying capacity to make this water safe for release into lakes and streams [7]. Extensive animal production and agricultural activities generate a substantial amount of waste. For example, in the St Petersburg region, there are 11-106 poultry (400 000–450 000 tons of dung per year), 150 000 animals (1.5x10^6 m^3 of liquid waste per year) and 220 000 livestock based on estimations [8]. Approximately, 344 abattoir factories are sited in Thailand and many are within the Bangkok vicinity. Liquid effluents from these abattoirs consist of largely organic matter, grease/oil and nitrogenous compounds (proteins and amino acids) [9]. In the meat industry, important pollutant parameters are; suspended solids, total dissolved solids, Biological Oxygen Demand, Chemical Oxygen Demand, FOG (fats, oils and greases), colour and water use [10]. Furthermore, abattoir wastes increase levels of phosphorus, N, solids and BOD5 of the receiving waterbody, potentially leading to eutrophication [1].

Abattoir wastewater composition

Proper procedures for the assessment of features of the waste disposed of by the meat processing industry are a difficult task. To monitor a particular plant and its related wastes is difficult due to several processes in addition to several components of procedures used in carcass processing [10]. Moreover, a significant amount of pollution load in form of effluents released from abattoirs are said to be fluctuating periodically [11]. Liquid effluents discharged from the abattoirs is tremendously complicated in terms of treatment or purification because of many reasons; its unique characteristics, variable composition at the time of release and significant amount of mineral, biogenic and organic matter [12]. Primary indices of pollution, such as wastewater composition can serve as the primary indicator of pollution. The indicator components include suspended solids COD, organic nitrogen, BOD and fats which are normally many times higher compared to average sewage discharged from households. Due to such disparity of industrial and domestic effluents, abattoir wastewater cannot be directly released to natural water bodies or a township sewage discharge system. Chemical and biological pollutants in the abattoir effluents are in form of colloids, suspended solids and dissolved compounds [13].

Regulatory agencies prohibit the direct discharge of the effluents and solid abattoir wastes into the environment because these are potential pollutants. Hence, this can decrease harmful ecological hazards and therefore treatment, filtration or purification is required before subsequent discharge into environment [14]. Effluents from meat industry operations such as animal slaughtering and processing contain high concentrations of fat and protein which are known to provide nutrients for bacterial growth. Wastewater also consists of the following: water from washing floors and equipment; water use for washing the before animal slaughtering; water from washing animal houses and animal farms; water use for washing viscera, internal organs and animal processing wastewater. Additionally, fat, blood, hair, internal organs and viscera, bones, urine and faeces as well as bacteria and another microorganism which are harmful to the public are found in water used during meat processing [15,16]. Moreover, bye products in animal slaughtering provide meat and offal which are generally categorized into comestible and non-comestibles. By-products represent approximately 60 to 70% of the processed animal, of which about 40% produce comestibles and 20% non-comestible products [17].

In many developing countries some by-products are thought to be edible while in developed countries are used as casings for sausages. Averagely about 12% of the total protein in the lean meat was associated with the bye products of the meat industry [18]. Below are some of the methods used by abattoirs for treatment of wastewater before discharge into the environment.

Primary treatment

Pollution control may be a very costly procedure and is reported to be increasing and usually leads to the high cost of municipal surcharges and in most cases, food processors have no options but to find alternative ways for primary treatment of effluents before discharge before secondary treatment [19].

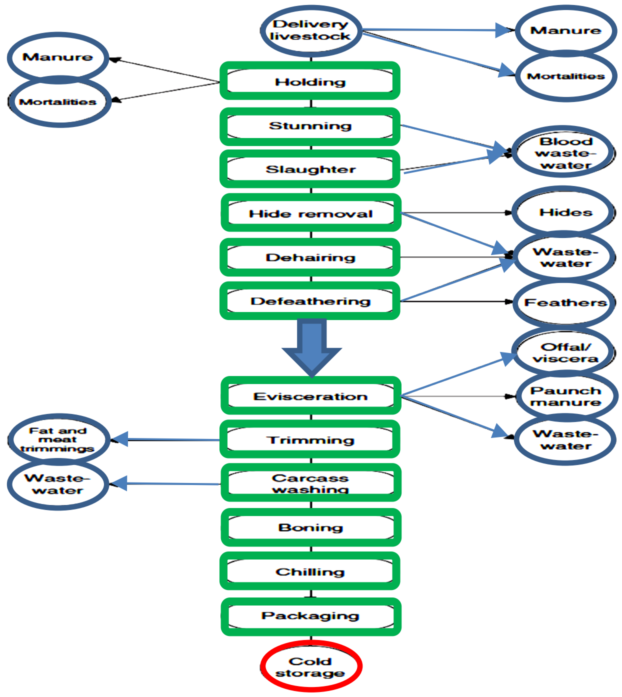

Fig. 1. Abattoir Waste Treatments.

Some of the methods increasingly adopted for primary treatment of wastewater include physicochemical methods before its biological treatment because of the stringent requirements related to the level of effluent treatments and the requirement to filter all organic contents before its release into the environment [20]. The main processes involved in wastewater treatment are those used to remove colloidal or suspended waste that causes turbidity and change of colours. The commonly applied method is referred to as coagulation/flocculation. Removal of suspended material and organic matter is an important essential feature of coagulation/flocculation in primary wastewater treatment. Floc forming chemical is required to remove suspended solids and organic material which can easily be segregated from water by flotation, adsorption or settling [21].

New coagulants are developed both inorganic and organic over the last two decades and have been applied to accelerate the removal of total suspended solids and organic matter in the treatment of effluents from Abattoirs [22]. The efficiency of the flocculation process and the rate at which the waste can be removed depends on mixing rate, temperature, sequential addition of flocculants and coagulants into the effluent. When Flocculants dissolve in wastewater, it may exist as in either non-ionized or ionized state. It is referred to as soluble polyelectrolytes when ionized [20].

Settling, screening and dissolved air flotation (DAF) is commonly used to date for suspended fats and oil, greases and solids removal in wastewater from Abattoirs. Reduction in 75–80% BOD5 can be achieved through the process and have the additional benefit of eliminating the high volume of nitrogen and phosphorus [23]. Furthermore, the pollutants found in effluents can be separated through the process of flocculation or coagulation. Comparison between the particle size distribution before and after the application of a coagulant can be used to determine the effectiveness of the processes [24.25].

The process of chemical oxygen demand is used to remove or reduced the large volume of nutrient, between 32 to 90% can be accomplished using air flotation [26]. It was observed that Air Floatation units decrease waste by about 50% approximately. Most often polymers and flocculants are chemicals frequently combined before the floatation process which aimed at enhancing protein agglutination and precipitation as well as flotation of fat molecules [27]. Furthermore, PAX-18, Al_2 $(SO_4)_3$+PA polyelectrolyte and $Fe_2(SO_4)_3$+anionic polyacrylamide can be mixed for effective COD removal rates, other compounds showed variations in their functions in response to pH. Similar research was conducted to enhance the efficiency of a biological treatment process using enzymatic treatments to hydrolyze or reduce the volume of fat molecules in abattoir effluents.

Wastewater samples with 2.5–3.0 g/l of fat particles were mixed with the enzyme at room temperature for 4 hours. After which it led to a decrease in fat volume by 60% with an increase in free long-chain fatty acids [28]. In this manner, a pancreatic enzyme (PL-250) was shown to be the most reliable in decreasing fat volume and increasing free long-chain fatty acid (LCFA) concentration. Nevertheless, the efficiency of primary treatment is arguable because the pollution removed only transferred from one form of waste (liquid) to another (usually solid wastes), which may also require treatment. Newer processes such as Co-composting and co-digestion have been widely used because many type wastes to be treated biologically are characterized by a lack of nutrients and porosity to support microbial growth. Hence, combination with similar wastes remained a promising approach towards overcoming these obstacles [29].

Secondary treatment

Anaerobic digestion

According to previous records, biological processes were earlier adopted to treat some industrial, municipal and animal wastes and the major biological waste treatment processes commonly use anaerobic treatment using microorganism that survives in the absence of oxygen [30-32]. The effectiveness of the process solely dependent on the composition and type of the material to be digested or treated [33]. Methane gas can eventually be obtained from animal wastes produced in confinement operations during the process. The waste can be collected easily as it accumulates in large quantities. Therefore, anaerobic digestion is a reliable option for the treatment of such materials [34,35]. Consequently, a problem from both pollution control and energy conservation may be solved through the anaerobic digestion process, since it can decrease the BOD5 significantly with the production of biogas in the form of methane [31]. In addition to producing biofuel for energy use, the process also eliminates pathogens and provide a high yield of stabilized material which can be used in agriculture as fertilizers [6]. Hydrolysis, acidogenesis and methanogenesis are the major phases in anaerobic digestion [36]. Physical separation of the three phases was previously proposed to result in an improved process as each may proceed under optimal conditions [37,38]. Additionally, optimization of the various conditions to improved methane production is one of the promising approaches to making anaerobic digestion more effective and therefore, more economically attractive [31]. The development of anaerobic digestion process involved the application of varied temperature ranges including mesophilic temperatures (35 °C) to thermophilic temperatures (55–60 °C) for effective waste management. The commonly used anaerobic digesters work either at mesophilic or thermophilic temperatures [39].

Anaerobic digestion of abattoir wastes often leads to a substantial increase in the concentration of ammonia-nitrogen due to protein disintegration. Eventually, the end product (ammonium) of the protein breakdown may be so excessive that it can affect the decomposition of other organic compounds, the production of volatile fatty acids (VFAs) and methanogenesis [40]. Generally, an increase in nitrogen concentration in the digester leads to an unstable digestion process and biogas production began to drop. In this regard, therefore, ammonium toxicity creates a serious setback during the anaerobic treatment of protein-rich wastes [41]. Other organic compounds such as oil and fats may bring about some problems during the process due to their potential to produce floating scum and accumulated long-chain fatty acids (LCFA) [42-44].

Accumulation of volatile fatty acids (VFA) accumulation in large volume can alter methane gas production while increased hydrogen levels can affect propionate- and butyrate-degrading acetogenins [45]. The mechanism for long-chain Fatty Acid accumulation involved precipitation and adsorption with divalent ions and entrapment of the waste in the flocculent structure of the sludge. Furthermore, the entrapped waste could be efficiently mineralized followed by enhanced specific methanogenic activity [46]. Many researchers have investigated the practicability of efficient abattoir wastes treatment by anaerobic digestion. In a typical example of such a laboratory-scale anaerobic down-flow fixed bed reactor was used. Abattoir waste is usually a mixture of various components. Investigations were made on the efficient waste treatment of effluents with different mixtures such as intestinal contents, stomach, rumen and liquid manure both in pilot and laboratory scale. The results have conclusively found that mixtures with animal by-products representing 19–38% of the total dry waste were digested in continuous-flow stirred tank reactors at pilot and laboratory scale [47,48].

Slaughterhouse wastewater can be efficiently treated by use of high-rate anaerobic processes, particularly with the use of a reactor. For the fact that COD removal efficiency dependents on the type of the reactor and the loading rate of a reactor filled with abattoir wastes, the percentage COD removal varies. Hence, anaerobic digestion specifically using membrane bioreactor is an effective process for the treatment of abattoir wastewater. Moreover, methane production is directly proportional to the digestion time. Methane production seems to be higher in the digestion of hog and poultry wastes compared to chicken manure and cattle slurry. Anaerobic digestion is said to be suitable for the treatment of abattoir wastewater due to its high level of COD removal that can be achieved at a considerably lower cost than comparable aerobic treatment systems. It can also produce more methane-rich gas and be used as a fuel compared to aerobic digestion. Combined treatment of several wastes with complementary characteristics can be achieved using improved anaerobic digestion. This improved technology is often referred to as co-digestion which gives an added advantage to the anaerobic digestion [49].

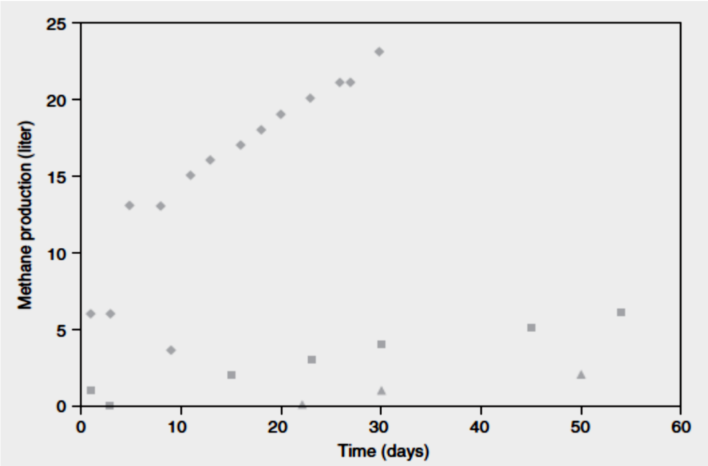

Fig. 2. Methane production during anaerobic digestion of Different slaughterhouse wastes; piggery wastewater [39] (■), hog and poultry waste [45] (◆) and chicken manure and cattle slurry [44] (▲).

Numerous literatures about the utilization of co-digestion of organic fraction for agricultural residues and municipal solid wastes, organic solid wastes and sewage sludge are available [50]. Many have reported that during the co-digestion waste which contained animal fats, the volume of methane in biogas slightly increased from 58 (steady-state) to 61%. On the other hand, when animal fats were replaced with vegetable oils, only a slight increase was recorded [51].

Aerobic digestion

The criteria for selection of wastewater treatment process depending on various factors; volume and type of influent, qualities of effluent and investment and operating cost [52]. The main purpose of any effluent treatment is to eliminate or reduce the suspended particles and to remove or decrease the soluble organic pollutants.

Biodegradation is the main technology that utilizes adsorption of microbes in activated sludge to oxidize and degrade the suspended protein, fat and other carbohydrates [15,52]. In aerobic digestion, the air is used by microbes to degrade pollutants and is proved to be a highly effective and easier method for degradation of organic pollutants, including odorants, though its operational cost is expensive. However, the heat generated during the process can be recovered and used as a source of energy; thereby providing support for the treatment cost [53]. Also, odours and pathogens in the wastewater can be reduced effectively by using the process [54].

It is generally known that the effect of wastewater treatment in a sequential bioreactor (SBR) mainly relies on the optimum process parameters, i.e. activated sludge loading, aeration intensity, the ratio between stirring time and aeration time and hydraulic retention of wastewater in an aeration chamber [12].

Composting

Composting is a generally used process for organic waste disposal and has been recognized as potential as well as an effective procedure for the treatment of waste before the land application [55,56]. It is described as a biological process which utilized naturally occurring anaerobic microorganisms to transform biodegradable organic matter into a humus-like product [57]. Humus can be used as organic fertilizer in agriculture because of its high nutrient composition. Microorganisms that survive at medium temperature range (Mesophiles) and high temperature-loving microbes (thermophilic) usually partake in the composting process and their succession is essential in the efficient control of the process [58-60]. Consequently, the process eradicates pathogenic microorganisms. However, it converts nitrogen from unstable ammonia to stable organic forms, decreases the amount of waste and enhance the quality of the waste [56]. A substantial amount of organic manure which contained protein and lignocellulosic materials are frequently released from Poultry farms.

To reduce the environmental effect of direct discharge of these liquid and solid poultry manures is prohibited because they are pollutants, thus waste treatment before land-filling is mandatory [14]. Chemical and biological stabilization of soluble nutrients found in the waste can be used to convert the liquid pollutant into more stable organic forms by composting before application to farmlands. Through this process environmental issues linked with raw manure application could be lessened [4]. The acceptance of composting, however, depends on how well the operating strategies used were developed for both environmental protection and product quality [4].

Composting offers an inexpensive option for disposal of all dead animals, wastes generated by butchers and is an alternative for meat industries who find it difficult to discard animal blood [26,61]. Technical know-how, sufficient space and regular maintenance and capital investment are some of the pre-requisite for building a composting site [26].
Many types of composting methods have been developed but three methods are frequently used:

i. windrows (a method used at Illinois State),
ii. aerated static piles (windrows with a perforated pipe laid within the pile) and
iii. Bins or aerated chambers.

Possibility of composting meat wastes, barley waste with liquid poultry manure has been studied and results showed that materials composted reached high temperatures within 4 days, lasting for more than 10 days; thereafter the temperature decreased rapidly to moderate levels. Organic matter loss in the co-composting of barley waste with liquid poultry manure was reported to be around 35%. Available potassium and phosphorous composition ranged from 0.7 to 2.2% and 3.4 to 3.8% respectively. According to the findings, the volume of ammonium in the final products seemed to be high. [14]. Similarly, a report from other research conducted to identify through which composting could be used for treating carcasses manure and litter as well as to determine factors which affect the composting process. Based on the findings, carcass composting can significantly decrease the cost of carcass disposal [56].

During composting of meat wastes products such as cattle dung and poultry waste changes in the microbial population, organic carbon, total nitrogen, carbon/nitrogen ratio, activities of cellulase, xylanase and protease were reported. Nitrogen in the poultry waste was lost in the process resulting in an initial increase in the C: N ratio which decreased further due to decomposition. Within 4 and 8 weeks of composting, the activities of protease, cellulose and xylanase reached their maximum values. Additionally, hard-to-degrade and insoluble animal proteins were observed to be present all over animal bodies [60]. A substantial amount of these proteins are produced by the meat industry in combination with organs, hard tissues and bones which finally find its way into the environment as industrial waste and disposal of such heavy industrial waste are extremely difficult. Incineration is the best alternative for most hard-to-degrade animal proteins [62-64]. However, incineration has ecological problems attached especially in terms of an apparent energy loss and the generation of a large volume of carbon dioxide. Thus, environmentally friendly and cheaper alternatives are urgently required to tackle the problem. The major hard-to-degrade animal proteins are extracellular matrix proteins (EMPs). Poultry processing and the leather industry produce a high number of keratins. [65,66]. Comparably, prion proteins are produced in much smaller volume but create more critical problems due to possession of highly aggregated, hard-to-degrade amyloid isoforms that cause bovine spongiform encephalopathy (BSE). Prion proteins have drawn general attention in recent times due to their severe pathogenicity in meat. Though not fully characterized, it showed considerable resistance to most chemical and physical methods applied for the inactivation of conventional pathogens [67-69].

Thermophilic bacteria that grow at an elevated temperature range are used in the decomposition of these hard-to-degrade animal proteins because at high temperatures such proteins tend to gain plasticity ant, therefore, more vulnerable to protease attack (Suriyama *et al.*, 2005). However, proteins are denatured rapidly at high temperature (approximately 80°C) which enhance the growth of extremely thermophilic bacteria. Moreover, moderately thermophilic bacteria that show an optimum temperature for growing below about 80°C are preferred to extremely thermophilic bacteria in terms of the energy cost required to sustain bacterial growth at high temperature [71].

CONCLUSION

Environmental pollutants released through wastewater by abattoirs may be complicated due changes brought about by additional substance used during animal processing. Several methods adopted by abattoirs were reported to be effective. However, the need for improvement in line with environmentally friendly guidelines is recommended.

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