PHYSICO-CHEMICAL CHARACTERIZATION AND TREATMENT OF SELECTED FOOD INDUSTRIAL EFFLUENT BY COAGULATION TECHNIQUE

Madu, K.[1]., Okoronkwo, G. O.[2] and Okoronkwo, P. C.[3]
[1]Department of Mechanical Engineering Chukwuemeka Odumegwu Ojukwu University Uli
[2]Department of Chemical Engineering Chukwuemeka Odumegwu Ojukwu University Uli
[3]Department of Electrical and Electronics Engineering Chukwuemeka Odumegwu Ojukwu University Uli
Email: madukc@yahoo.com, ogeorgeonyeka@gmail.com and pamela.okoronkwo@gmail.com.

ABSTRACT
Food processing industries consume large quantities of water. The food industrial effluents in general are characterized by high Biological Oxygen Demand along with fats, oil–grease and many other recoverable nutrients like Nitrate and Phosphorous. In the present investigation thorough treatment studies were carried out on alkwa abattoir effluents in Anambra state, Nigeria using alum, as coagulant. Physicochemical characterization of the effluent was also carried out to check the pollution potential of this wastewater. More emphasis was given on the representative water parameters mainly pH, Electrical Conductivity, Total Dissolved Solids, Biological Oxygen Demand, Turbidity etc. The coagulation was performed with alum at different dosage intervals in order to check the variations in effluent parameters. Present studies revealed that coagulation has better ability to reduce the abattoir wastewater parameters.

Keywords: Abattoir Wastewater, Coagulation, Physico-Chemical Parameters, Statistical Analysis.

1.0 INTRODUCTION

Ever increasing industrialization and rapid urbanization have considerably increased the rate of water pollution. The dwindling supplies of natural resources of water have made this a serious constraint for industrial growth and for a reasonable standard of urban living. The environmental protection agencies have imposed more stringent regulatory prohibitions to protect the environment. This has made the water treatment more expensive and to comply with the discharge quality standard itself, is becoming a huge burden for the industries. The pollution of water resources due to discharge of poor quality effluents poses a serious threat to human beings and aquatic organisms since they rely on water for sustenance. The problem is more severe in developing countries where rapid population growth and industrialization has increased complexity of effluents [1–3]. In recent years, researchers have shifted their interests in possible reuse and recycling of various effluents where food industries are no exceptions to it [4]. In most cases, these effluents are not treated and are simply thrown into rivers where they contribute to eutrophication by addition of phosphorus and nitrogen compounds. Treating food effluents is of crucial importance not only for the environment, but also for the purpose of recycling water for use in industrial processes. The physico-chemical processes suffer the disadvantage that reagent costs are high and the soluble COD removal is low [5]. Moreover, chemical treatments could induce a secondary pollution due to the fact that chemical additives may contaminate the treated water. Food industry wastewater demonstrates a complicated system containing different components, including pollutants coming from the processed raw materials, chemicals and residues of technological additives used in individual operations. In reference to food industry wastewater, treatment processes have to assure first of all required quality of discharged effluents.

Food industry is of crucial importance to India and contributes 35% of the total Asian food. It is the world's largest food producer in the entire globe consuming almost 100% of its own food production. The food industries require large quantity of water for the purpose of washing of cans, machinery and floor, the liquid waste in a food originates from manufacturing process, utilities and service section. The clean water is used in various stages of food operations, such as, meat processing, cleaning, packaging and cleaning of the milk tankers and releases the wastewater which is known as food effluent. Water is used for processing in the ratio of 1:10 (water: milk) per liter of milk. Food wastewater has high concentration of dissolved organic components like proteins, lactose, fat and minerals [6] and it is also malodorous because of the decomposition of some of the contaminants causing discomfort to the surrounding population. The food industry generates huge amount of wastewaters, approximately 0.2–10 L of waste per liter of processed food [4]. Food wastes are largely neutral or slightly alkaline and have a tendency to become acidic quite rapidly, because of the fermentation of food sugar to lactic acid. The lower pH may lead to the precipitation of casein. Food wastes are characterized by strong butyric acid odor and heavy black flocculated sludge masses [7]. Fats, oil and grease, also called FOG and can have negative impacts on wastewater treatment systems [8]. Oil and grease is composed primarily of a fatty matter from animal and vegetable sources, hydrocarbons of petroleum origin, the interferences include sulfur compounds and certain organic dyes [9]. Organic load is basically constituted by food (raw material and dairy products), reflecting an effluent with high levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), oil and grease, nitrogen and phosphorus. Moreover, the automatic cleaning system CIP (cleaning in place) discards rinse waters with pH varying between 1.0 and 13.0, further complicating the question of treatment [10].

Alum (Aluminum sulfate) is a nontoxic material commonly used in water treatment plants to clarify drinking water. Cooke et al. [11] adopted 50 mg Al/l as a safe upper limit for post-treatment dissolved aluminum concentrations. Waste control is an important aspect of resource management control and an essential part of food plant operations [12]. Water management in the food industry is well documented, but effluent production and disposal remain a problematic issue for the food industry [13, 14]. Effects of the presence of these wastes include, contamination of drinking water, killing of aquatic life, increased danger in swimming and objectionable physical conditions such as off odors and accumulation of debris. Land disposal of farm effluents can cause water logging conditions and contamination of groundwater along with surface water by leaching and runoff in nearby areas. The chemical methods may cause further contamination to the environment and while breaking down the organic pollution, microorganisms deplete the oxygen from water [15].

In the present investigation, an attempt has been made to study the physicochemical characterization and effects of alum coagulation techniques on the selected abattoir food industrial effluents. The treatments were studied in relation with important water quality parameters mainly associated with estimation of pH, EC, TDS, BOD, Turbidity and etc. of the treated effluents.

2.0 MATERIALS AND METHODS

Abattoir wastewater samples were collected from abattoir site located in Awka city in Anambra state, Nigeria. The samples were labeled and preserved as per standards methods. The methods used for analysis were in consistent with as mentioned in 'Handbook of Water Analysis' [16].

2.1. Electrical Conductivity (EC), Total Solids (TS), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS)

(TS, TSS and TDS)

Electrical conductivity and total dissolved solids of the diluted effluent concentrations namely 1%, 2%, 3% and 4% were determined by using ELICO EC-TDS meter (CM 183, Make-India) where electrode was directly dipped into the respective solutions to display result on a digital scale. Total solids were determined by gravimetric method and then suspended solids were calculated by using equation

$$TS = TDS + TSS \qquad (1)$$

2.2. Turbidity and pH

Turbidity of the sample was determined by using CL 52D ELICO Nephelometer while pH of the samples was recorded by using ELICO LI 127 pH meter.

2.3. Nitrate

Nitrate nitrogen is the most highly oxidized form of nitrogen found in wastewaters. Where secondary effluent is to be reclaimed for groundwater recharge, the nitrate concentration is important. The nitrogen present in fresh wastewater is primarily combined in proteinaceous matter and urea. Decomposition by bacteria readily changes the form to ammonia. The age of wastewater is indicated by the relative amount of ammonia that is present. In an aerobic environment, bacteria can oxidize the ammonia nitrogen to nitrites and nitrates. The predominance of nitrate nitrogen in wastewater indicates that the waste has been stabilized with respect to oxygen demand. Nitrates, however, can be used by animals to form animal protein. Death and decomposition of the plant and nitrates can be reused to make protein by algae and other plants, it may be necessary to remove or to reduce the nitrogen that is present to prevent these growths.

2.4. Phosphorus Content

Phosphorous may appear in many forms in wastewater. Among the forms found are the orthophosphates, polyphosphates, and organic phosphate. For our purpose, we will call of these together under the heading "total phosphorous (as P)". Phosphorous is also essential to the growth of algae and other biological organisms. Because of noxious algal blooms that occur in surface waters, these is presently much interest in controlling the amount of phosphorous compounds that enter surface waters in domestic and industrial waste discharges and natural runoff.

2.5. Biological Oxygen Demand (BOD)

BOD was estimated by preparing required volume of dilution water with the addition of nutrients namely phosphate buffer, magnesium sulfate, calcium chloride and ferric chloride. The diluted sample was transferred to BOD bottles. After determining initial DO, final DO was estimated of the bottles kept for incubation period of five days. The bottles kept for DO determination and blank were fixed by adding 2 ml manganous sulfate ($MnSO_4$), 2 ml of alkali iodide azide ($NaOH + KI + NaN_3$).

2.6. Fats, Oils and Grease Contents

Fats and oils are the third major component of foodstuffs. Fats and oils are contributed to domestic wastewater in butter, lard, margarine and vegetable fats and oils. Fats are also found in meats, seeds, nuts and in certain fruits. The term “grease” as commonly used, includes the fats, oils, waxes and other related constituents found in wastewater. The grease content of wastewater can cause many problems in both sewers and waste treatment plants, if grease is not removed before discharge of the waste, it can interfere with the biological life in the surface waters and create unsightly floating matter and films.

2.7. Heavy Metals

Heavy metals and minerals mainly Zn, Fe, Pb and Mn were estimated from the abattoir wastewater effluents. The samples were digested following the standard method by Toth et al. [17] and were estimated using Atomic Absorption Spectrophotometer (Perkin-Elmer, 3030 A).

2.8. Alum Treatment

10 g alum was added to 1 L of distilled water to prepare stock solution. Each 1.0 mL of this stock solution will equal 10 mg\L (ppm) when added to 1000 mL of water to be tested. Total six dosages were applied 40, 80, 120, 160, 200 and 240 mg/L, respectively and samples were analyzed.

Table.1. Characterization of Alkwa food industrial effluents

Sr. no.	Parameters	Abattoir water
1	Color	Dark gray
2	Odor	Unpleasant
3	pH	6.19 – 7.98 *7.35 $\pm$2.16
4	EC (μS)	595.00 – 1413.00 *863.00 $\pm$403.50
5	TDS	43.80 – 60.18 *51.25

		±16.11
6	TSS	3.92 – 7.88 *5.75 ±2.18
7	Turbidity (NTU)	172.00 – 242.00 *221.80 ±68.98
8	Oil and grease	17.70 – 36.00 *27.61 ±10.1010
9	DO	68.40 – 73.20 *71.18 ±19.98
10	BOD	368.00 – 386.00 *408.80 ±113.57
11	Nitrate NO_3^-	4.272 – 19.19 *11.72 ±7.21
12	Phosphate PO_4^{3-}	17.184 – 26.082 *20.90 ±6.79
13	chlorides	84.00 – 214.00 *127.40 ±61.61

All Values in mg/L except EC in μS and turbidity in NTU; ±SD, *AV

2.9. Statistical Analysis

Mean and standard deviation of the raw data were calculated by using MAT Lab 7.9 Software.

3.0 RESULTS AND DISCUSSION

The results of the present investigation on the abattoir wastewater in Alkwa city in Anambra state, Nigeria and its follow-up discussions are as depicted in the following sub-headings, followed with conclusion.

3.1. Characterization of the Food Industrial Effluent

In the present investigation, initial characterization of the effluent showed (Table 1) varying levels of various physicochemical parameters where dark gray effluent along with unpleasant odor were observed. The average pH of the abattoir effluent was observed as to be neutral. Average electrical conductivity was also observed to be high across the abattoir with a value of 863.00 μS. In general, average total solids were observed to be below FEPA limits as compared with the effluents standards. Turbidity of abattoir effluent was high with a value of 221.80 NTU indicating higher solids and organics. Dissolved oxygen and BOD were also higher (71.18 mg/L and 408.80 mg/L) than the FEPA standard limits for this abattoir effluent 7.5 mg/L and 50 mg/L, respectively. In general, it was also observed that nitrate and phosphate were either within or above FEPA standard limits in all the abattoir effluent samples indicating the fertilizing values after sufficient treatment and possible recovery. Chlorides were observed to also be high in abattoir effluent by a value of 127.40 mg/L. From the initial characterization of the effluent, it can be concluded that abattoir effluent was with more pollution potential but it should also be noted that the concentration and polluting strength of the effluent varies largely and dependent on the season and type of process used in the industry.

Related food industrial processing effluents are generated in an intermittent way and the flow rates of these effluents change significantly [18]. The types and size of processes and equipment used are determined by raw material inputs and the finished products manufactured. These related food industrial processes generates about 0.2–10 l of effluent per liter of processed food[19] with an average generation of about 2.5 l of wastewater per liter of food processed [20]. Food industrial processing wastewater contains food solids, detergents, sanitizers, food wastes, and cleaning water. They are characterized by high concentrations of nutrients, and organic and inorganic contents. Significant variations in physicochemical parameters have been reported by various investigators of industrial food wastewater. If the COD value is much bigger than the BOD value, the organic compounds in wastewater are slowly biodegradable [21].

Table 2: Heavy Metal Content of Alkwa Abattoir Food Industrial Effluents (Values in mg/L)

Effluent	Zn	Fe	Pb	Mn
Abattoir water	1.351 – 5.689 * 3.301 ±1.70	2.432 – 9.018 *4.49 ±2.91	0.011 – 0.069 *0.04 ±0.03	0.871 – 1.900 *1.36 ±0.54

±SD, *AV

3.2. Minerals and Heavy Metals

Table 2 shows heavy metal content of Alkwa abattoir food industrial effluents. The nickel and cobalt were absent in all industrial effluent samples considered. Concentration of zinc was observed (3.301 mg/L) to be above the FEPA standard limits (< 1 mg/L). Iron manganese contents were observed (4.491 mg/L and 1.36 mg/L) to be below the FEPA standard limits (20 mg/L for iron and 5 mg/L for manganese), respectively. One of the interesting features of the present investigation was the presence of lead in all the samples. Presence of lead was observed in the abattoir effluent with a value of 0.04 mg/L to be within the FEPA standard limits (< 1 mg/L). Oil and grease as expected were observed to be present in these food industrial effluent samples with average (27.61 mg/L) and were above FEPA limits of standard (10 mg/l). Heavy metals and other toxicants enter in soil which is irrigated with polluted waters and show toxic effects on plants and animals [22]. Trace elements (iron, zinc etc.) and other heavy metals (cadmium, arsenic, chromium, mercury etc.) also enter in abattoir effluents through therapeutic compounds and organic materials from pesticides [25, 26].

Table 3: Changes in pH, EC and TDS of food industrial wastewater after treatment with alum

Dose (Mg/L)	pH	EC (μS)	TDS(mg/L)
80	4.20 – 12.50 * 8.35 ±0.05	290.00 – 630.00 *460.00 ±120.00	9.68 – 30.80 *20.24 ±0.88

±SD, *AV

Table 4: Changes in BOD and turbidity of food industrial wastewater after treatment with alum

Dose (Mg/L)	BOD(Mg/L)	Turbidity (NTU)
240	135.00 – 368.00 * 251.50 ±18.50	100 – 200 *150.00 ±50.00

±SD, *AV

3.3. Alum Treatment

It was clear from the result obtained (Table 4) that the BOD value for the effluent decreased serially. Turbidity also showed maximal decrease after addition of 240 mg/L of alum to the effluent. In Table 6, maximal decrease in electrical conductivity (460.00μS) was observed when 80 mg/L was added to the abattoir effluent. TDS value was also decreased after the addition of 80 mg/L of alum and the value was 20.24 mg/L, respectively. Turbidity showed decrease at 240 mg/L of alum in all the abattoir effluent samples. Coagulation-flocculation is one of the most important physicochemical treatment steps in industrial wastewater treatment to reduce the suspended and colloidal materials responsible for turbidity of the wastewater and also for the reduction of organic matters which contributes to BOD and COD content of the wastewater [23]. The performance of a particular coagulant depends upon the quality of the wastewater. Alum was found to be effective coagulant in reducing solids, organics and nutrients in the wastewater industry effluent to reuse it in irrigation but performance of the coagulants was highly dependent on pH and dosages [24].

CONCLUSION

In the present study, satisfactory diminution of various parameters, mainly of turbidity, BOD, EC, TDS etc. were observed. From the initial characterization of the effluents, abattoir effluent was observed with more pollution potential which varies with the season and type of process used in the industry. Toxic parameter (lead) was observed in all the food industrial effluent samples (abattoir) and may cause damage to the aquatic and other life forms through bioaccumulation. Alum dosage is a convenient route for the treatment of the food industrial effluents. After alum dosage study, BOD, Turbidity, EC and TDS showed decrease in values which also indicated that the technique was best and more efficient to treat such type of effluent. We also recommend that the effluent should be used for irrigation purposes as it has good fertilizing value. Useful nutrients from this effluent can be recycled from the sludge. Alum dosage should be promoted for such type of food effluents and other highly complicated liquid wastes.

Conflict of interest

The authors declare no conflict of interest

Acknowledgments

Authors are thankful to all those that contributed in a way or the other and more especially to the Management of Geo-Chem. CCRD Nigeria Limited for constant guidance and encouragements.

REFERENCES

[1] A. Elhassadi, (2008), *Pollution of Water Resources From Industrial Effluents: A Case Study-Benghazi*, Libya, Desalination 222, (2008) 286–293.

[2] P. J. Oberholster, A. M. Botha, T. E. Cloete, *Biological And Chemical Evaluation Of Sewage Water Pollution In The Rietvlei Nature Reserve Wetland Area*, South Africa, Environmental Pollution 156, (2008) 184–192.

[3] F. Ntuli, K.P. Kuipa, E. Muzenda, *Designing Of Sampling Programmes For Industrial Effluent Monitoring*, Environmental Science and Pollution Research 18 (2011) 479–484.

[4] B. Balannec, M. Vourch, M. Rabiller-Baudry, B. Chaufer, *Comparative Study Of Different Nanofiltration And Reverse Osmosis Membranes For Dairy Effluent Treatment By Dead-End Filtration*, Separation and Purification Technology 42 (2005) 195–200.

[5] B. Demirel, O. Yenigun, T. T. Onay, *Anaerobic Treatment Of Dairy Wastewaters: A Review*, Process Biochemistry 40 (2005) 2583–2595.

[6] R. Mukhopadhyay, D. Talukdar, B.P. Chatterjee, A.K. Guha, *Whey Processing With Chitosan And Isolation Of Lactose*, Process Biochemistry 39 (2003) 381–385.

[7] V. B. Braio, C. R. G. Taveres, *Effluent Generation By The Dairy Industry: Preventive Attitude And Opportunities*, Journal of Chemical Engineering 24 (2007) 487–497.

[8] H. F. Castro, A. A. Mendes, *Some Biochemical Aspects Of The Anaerobic Degradation Of Dairy Wastewater*, Water Research 29 (2004) 1549–1554.

[9] W. L. Stuth, and M. Guichard, *Managing Grease and Oil In Restaurant Waste, In: R.W. Seabloom (Ed.)*, Proceeding of the 6th northwest on-site wastewater treatment short course, 1989, pp. 341.

[10] V. B. Briao, *Study of Pollution Prevention in a Dairy Industry* (Master's thesis), University of Maringa, Maringa, Brazil, 2000.

[11] A. Arumugam, P.L. Sabarethinam, *Performance of A Three-Phase Fluidized Bed Reactor With Different Support Particles In Treatment Of Dairy Wastewater*, ARPN Journal of Engineering and Applied Sciences 3 (2008) 42–44.

[12] Water Research Commission, *Waste and Waste-Water Management in The Dairy Industry*, WRC Project no. TT 38/89. Nasturv 4. Published by the WRC, Pretoria, South Africa, 1989.

[13] M. G. Healy, et al., *Biotreatment of Marine Crustancean and Chicken Egg Shell Waste, Environmental Biotechnology: Principles and Applications*, Kluwer, Academic publishers, The Netherlands, 1995, pp. 302–319.

[14] A. D. Cannon, K. R. Gray, A. J. Biddlestone, K. Thayanithy, *Pilot-Scale Development of A Bioreactor For The Treatment of Dairy Dirty Water,* Journal of Agricultural Engineering Research 77 (2000) 327–334.

[15] G. D. Cooke, R.T. Heath, R. H. Kennedy, M. R. McComas, *Effects of Diversion and Alum Application on Two Eutrophic Lakes*, 1978.

[16] S. K. Maiti, *Handbook of Methods in Environmental Studies (1 and 2),* ABD Publishers, Jaipur, 2004.

[17] S. J. Toth, A. L. Prince, A. Wallace, D. S. Mikkelsen, *Rapid Quantitative Determination Of Eight Mineral Elements In Plant Tissues By Systematic Procedure Involving Use Of A Flame Photometer,* Soil Science 66 (1948) 456–466.

[18] R. Kolarski, G. Nyhuis, *Use Of Sequencing Batch Reactor Technology For The Treatment Of High Strength Dairy Processing Waste*, Proceedings of the 50th Purdue International Waste Conference, 1995, pp. 485–494.

[19] M. Vourch, B. Balannec, B. Chaufer, G. Dorange, *Nanofiltration And Reverse Osmosis Of Model Process Waters From The Dairy Industry To Produce Water For Reuse*, Desalination 172 (2005) 245–256.

[20] E. V. Ramasamy, S. Gajalakshmi, R. Sanjeevi, M.N. Jithesh, S.A. Abbasi, *Feasibility Studies On The Treatment Of Dairy Wastewaters With Upflow Anaerobic Sludge Blanket Reactors*, Bioresource Technology 93 (2004) 209–212.

[21] L. Hiisvirta, *Teurastamojen Ja Lihanjalostuslaitosten Jätevesikuormitus Ja Jätevesien Käsittelymahdollisuudet*, Vesihallituksen projekti 7406 B, Oy Vesi-hydro AB, Kyriiri Oy, Helsinki, Finland, 1976.

.

[22] K. S. Patel, K. Shrivas, R. Brandt, N. Jakubowski, W. Corns, P. Hoffmann, *Arsenic Contamination In Water, Soil, Sediment and Rice Of Central India*, Environmental Geochemistry and Health 27 (2005) 131–145.

[23] N. Z. Al-Mutairi, L. Hiisvirta, *Teurastamojen Ja Lihanjalostuslaitosten Jätevesikuormitus Ja Jätevesien Käsittelymahdollisuudet*, Vesihallituksen projekti 7406 B, Oy Vesi-hydro AB, Kyriiri Oy, Helsinki, Finland. 1976.

[24] Z. Song, C. J. Williams, R. G. J. Edyvean, *Treatment of Tannery Wastewater By Chemical Coagulation*, Desalination 164 (2004) 249–259.

[25] M. McBride, G. Spiers, *Trace Element Content of Selected Fertilizers and Dairy Manures As Determined By ICP-MS*, Communications in Soil Science and Plant Analysis 32 (1-2) (2001) 139–156.

[26] H. L. Wang, G.N. Magesan, N.S. Bolan, *An Overview of The Environmental Effects of Land Application of Farm Effluents*, New Zealand Journal of Agricultural Research 47 (4) (2004) 389–403.