VOL. 15, NO. 23, DECEMBER 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2020 Asian Research Publishing Network (ARPN). All rights reserved.

www.arpnjournals.com

TREATMENT OF MEAT PROCESSING WASTEWATER USING COAGULATION AND SEDIMENTATION TECHNIQUES

Mona A. Abdel-Fatah[1], S. I. Hawash[1], and Ahmed Abd El Maguid[2]
[1] Department of Chemical Engineering and Pilot Plant, Engineering Research Division, National Research Center, El-Bohouth St., Dokki, Cairo, Egypt
[2]Sanitary and Environment Engineering Institute, Housing and Building National Research Center (HBRC), Dokki, Cairo, Egypt
E-Mail: monamamin7@yahoo.com

ABSTRACT
Meat processing plants as major food processing units consume a large amount of water. In this article, an experimental study of wastewater treatment collected from different meat processing plants in Egypt is demonstrated. Treatment of wastewater was investigated to remove the organic matters and pollutants to reuse the water in different applications like irrigation. Coagulation was used for the treating of wastewater from the meat processing plant. The results showed that coagulation is an efficient process for reducing pollutant in wastewater to the required permissible limits. Different coagulants and concentrations were used in the study. Optimum conditions for the coagulation process are flash mixing at 230 rpm for 1 min, flocculation for 15 min at 15 rpm, and a settling time of 1 hour. Maximum removal of organic pollutants was achieved using ferrous sulphate as coagulant and lime for pH adjustment with a dose of 300 and 400 mg/l respectively. COD and BOD_5 removal efficiency was 92 and 95% respectively. A detailed process for treatment of wastewater from meat processing plants was proposed. An engineering design of wastewater treatment unit is developed based on laboratory and bench scale study.

Keywords: meat processing, wastewater, coagulation, sedimentation, treatability study.

1. INTRODUCTION

The meat processing industry is one of the largest consumers of total freshwater used in the agricultural and livestock industry worldwide [1]. As a result of meat processing, these plants produce large amounts of wastewater and gaseous pollutants. An increasing attention to the treatment of wastewater and gaseous emissions is essential to reduce the harmful effect of these plants on the community. Food processing and agricultural wastewater composition vary considerably in biological oxygen demand (BOD_5) and pH according to the processed food (vegetable, fruit, and meat). The seasonal nature of food processing and post-harvesting treatment may increase the complexity of wastewater treatment [2]. In the poultry industry, chicken products are distinguished with the lowest water footprint (WF) among other meat products, such as pork, beef or sheep meat [3, 4].

The meat processing plants have a detrimental effect on the environment [5, 6]. The detrimental effect is observed with different scale processing units from small to large companies [7]. The production steps in a meat processing plants are cleaning of raw materials, removal of non-edible parts, and preparation of food products. The wastewater contains dissolved and suspended organic matter. It is estimated that the meat processing the plant generates a wastewater of around 5 l/Kg body weight of live animal [8, 9]. Meat processing wastewater may contain high levels of various pollutants. The wastewater treatment may vary considerably according to the nature and concentration of organic matter. Pollutants particles may vary in nature from coarse suspended (1 mm) matter, insoluble and slowly biodegradable matter, colloidal matter, and soluble matter [10,11].

There are numerous applicable technologies for meat processing plants wastewater. To select the suitable wastewater treatment processes, the following properties and constituents should be considered: Total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD_5), chlorides, nitrogen, fats, blood and bones [12]. Meat processing industry generates biodegradable organic matter between 1100 to 2400 mg O_2 L^{-1} as BOD and soluble fractions of 40-60% [13]. The optimum process should reduce the contaminants in the wastewater stream to the standard allowable limits before discharging water.

The anaerobic sequencing batch reactor (ASBR) is an effective treatment method for high COD and suspended solid streams [14]. The ASBR is distinguished with simple operation, flexible control, less manpower requirement, low sludge generation, economical process, and methane production [15]. In addition, several valuable by-products like oils and lards are produced which improve the process economics [16-18].

Physiochemical treatment is used effectively for the treatment of meat processing wastewater. Using physiochemical treatment, TSS was reduced by 85%. While BOD_5, and COD reduction was in the range of 62-78.8% and 74.6-79.5% respectively [19]. Chemical diffused air flotation (DAF) process was investigated for meat processing wastewater treatment using coagulant and coagulation aids. The process is not economically feasible due to a high cost of chemicals, maintenance, and operating costs. Cheaper separation treatment process like column flotation reduces the organic load efficiently at a reasonable price [20-22].

One of the most used technologies in industrial wastewater treatment is the coagulation/ flocculation process [23-30]. Coagulation/ flocculation technologies for industrial wastewater treatment are simple and efficient [24-30]. Coagulants can be classified as inorganic salts

©2006-2020 Asian Research Publishing Network (ARPN). All rights reserved.

(salts of multivalent metals), organic polymeric flocculants and biopolymers based flocculants. Each coagulant class is distinguished with different properties which can improve the process flexibility by manipulating the coagulants according to the wastewater composition [31]. The coagulants combine with fine inorganic, organic and metal particles, turning into heavy particle and settle down easily [32].

The objective of this study is to investigate the feasibility of treating wastewater discharged from meat processing plants, using chemical coagulation followed by sedimentation. The study includes an evaluation of applying coagulation process for treatment of wastewater from meat processing plants on the industrial scale. The goal is to provide new sources of water and reduce pollution as much as possible to conserve the environment, public health and sustainability. Finally, an engineering design for a treatment unit including a mixing vessel, and sedimentation tank is developed.

2. MATERIALS AND METHODS

2.1 Characterization of Wastewater from Meat Processing Plants

Composite wastewater samples were collected from different meat processing plants. The characteristics of the wastewater treated in the experimental study are shown in Table-1. The Egyptian regulating standards are shown in the fourth column.

Table-1. Wastewater characterization.

Parameters	Units	Water Quality	Permissible Limits
Water flow rate	**m^3/day**	**350**	**-**
pH		6.2 - 7.1	6 - 9
BOD_5	mg/l	880	< 30
COD	mg/l	1194	< 60
TSS	mg/l	270	< 30
Oil and grease	mg/l	446	< 5
Turbidity	NTU	258	1

As shown in Table-1, characteristics of meat processing plant wastewater indicate that wastewater is not complying with the Egyptian regulating standards for discharging into sewer network. An efficient and economical wastewater treatment technology should be implemented to improve the characteristics of the discharged water.

2.2 Treatment Study Procedure

Different types of coagulants [Ferrous Sulphate ($FeSO_4$), Ferric Chloride ($FeCl_3$), Aluminium Sulphate ($Al_2(SO_4)_3$)] were used with different doses to study the effect of coagulant material and concentration. Lime (CaO) was used for pH adjustment. $FeSO_4$ doses were varied between 100 to 500 mg/l. $FeCl_3$ doses were varied between 100 to 450 mg/l. $Al_2(SO_4)_3$ doses were varied between 16 to 160 mg/l. Lime was used according to to the required pH value, the doses were varied between 100 to 500 mg/l. All experimental runs were conducted using a jar test technique.

The coagulation/flocculation experiments were conducted using the following experimental procedure: adding coagulant dose to wastewater, flash mixing at 230 rpm for one minute, flocculation period for 15 min at 15 rpm, and finally the mixture was kept stagnant to settle down for one hour.

2.3 Design Considerations

The design consideration used to develop the detailed engineering design of the wastewater treatment plant is shown below in Table-2.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2020 Asian Research Publishing Network (ARPN). All rights reserved.

Table-2. Design consideration for developing a detailed engineering design of the wastewater treatment plant

Parameters	Units	Water Quality
Daily average flow	**m^3**	**350**
Hourly average flow	m^3	15
Balancing flow	m^3/h	20
Turbidity	NTU	300
Settable solids at	10 min 30 min	4.9 m^3/d 5.25 m^3/d
BOD_5 loading	kg/d	346.5
COD loading	kg/d	635.3
SS loading	kg/d	119
Oil & Grease loading	kg/d	156
pH		6.3 – 7.1

2.4 Proposed Treatment Unit

According to wastewater characteristics and the Egyptian regulating standards, a treatment process is suggested by considering the bench scale study, design consideration and experimental procedure. The suggested wastewater treatment process will contain the following components:

a. Collection tank
b. Buffering thank (pH adjustment)
c. Conditioning stirring tank for coagulants addition
d. Lamella settler
e. Sludge holding tank
f. Sludge thickener tank
g. Sludge drying system

3. RESULTS AND DISCUSSIONS

The experimental study including bench scale and laboratory experiments are the basis for developing the detailed engineering design of the treatment process. Figure-1 is a block flow diagram; which illustrates the main treatment plant (IWWTP).

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2020 Asian Research Publishing Network (ARPN). All rights reserved.

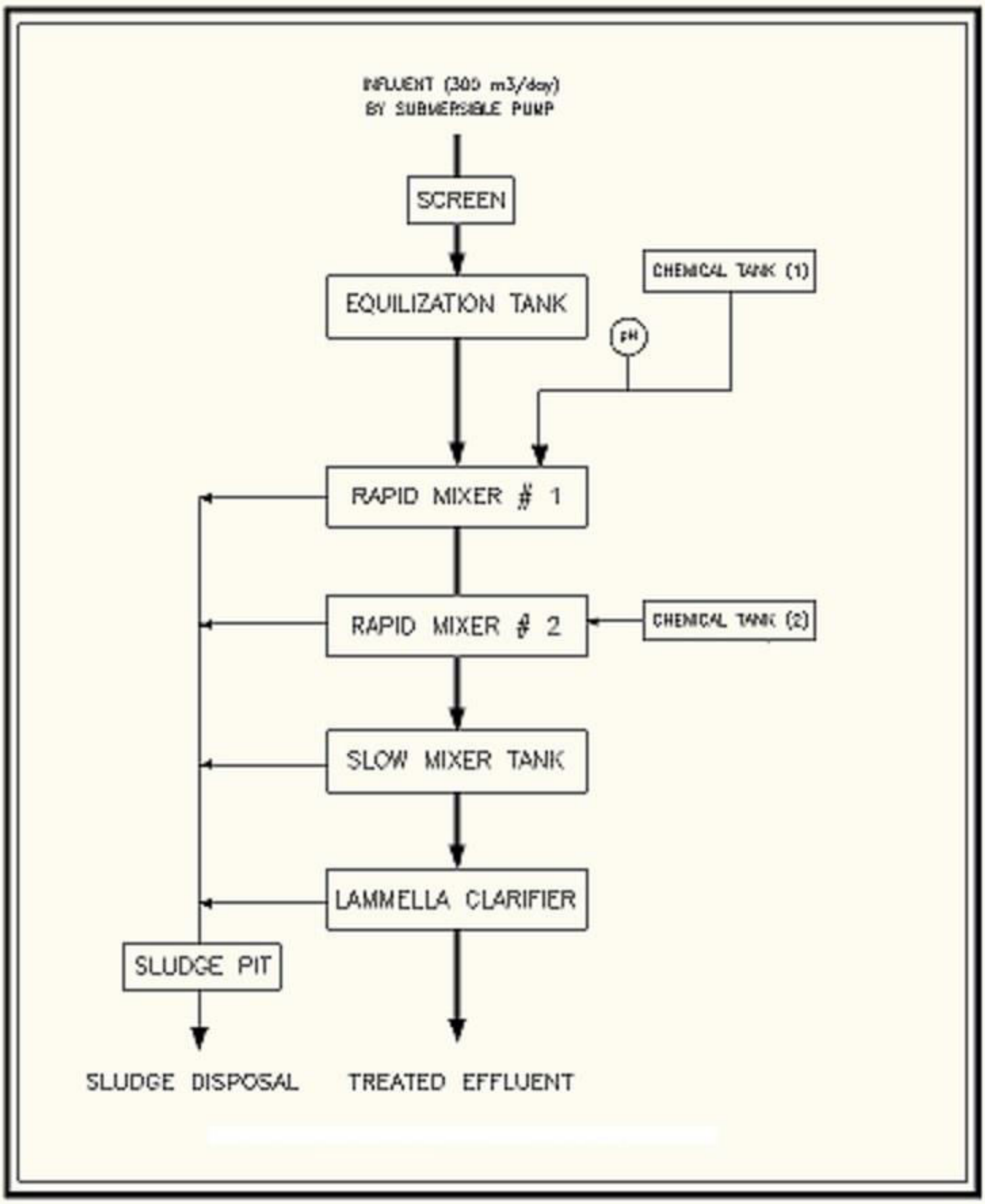

Figure-1. Block flow diagram of IWWTP

3.1 Treatment and Reagents Assessment

The efficiency of different coagulants was compared using different doses of coagulants in wastewater under study.

From experimental results, characteristics of treated water after coagulation are within the permissible limits for all pollutants according to the Egyptian standards. For example, COD of treated wastewater ranged from 400 to 500 mg/l using $FeSO_4.7H_2O$ as a coagulant. While using $FeCl_3$ as coagulant COD load was between 500 to 600 mg/l. If alum is used as a coagulant, COD value was 420 mg/l regarding suspended solid content after coagulation; its concentration was less than 100 mg/l.

Maximum removal of organic pollutants was achieved under the following conditions: ferrous sulphate as coagulant and lime for pH adjustment with a dose of 300 and 400 mg/l respectively. Table-3 illustrates the analyses of chemically treated effluent at optimum conditions ($FeSO_4.7H_2O$ as coagulant dose). It was found that annual chemical consumption of ferrous sulphate is 31.5 tons and 42 tons of calcium oxide.

VOL. 15, NO. 23, DECEMBER 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2020 Asian Research Publishing Network (ARPN). All rights reserved.

Table-3. Analyses of chemically treated effluent at optimum coagulant dose

Parameter	Unit	Raw WW	Effluent after Coagulants $FeSO_4.7H_2O + CaO$	Removal %
pH - value	-	6.3	8.6	
Turbidity	NTU	215	48.3	77.5
Settleable solids	ml/l	8	0.1	98.75
COD	mgO_2/l	1284	492	61.68
BOD	mgO_2/l	880	312	64.55
TSS	mg/l	200	68	66
TDS	mg/l	1600	1008	37
Oil and grease	ml/l	338	36.8	89.1

3.2 Design of Treatment Unit

According to the experimental study, the wastewater treatment process may include a screen for solids, oil and fats removal. The screen is followed by equalization tank for attenuation of the flocculation inflow and/or load followed by two rapid mixing tanks. Then, the coagulated stream is introduced to a slow mixing tank and a lamella clarifier. The products from lamella clarifier are treated water and sludge. The processes flow diagram of the treatment process steps are illustrated in Figure-2. In addition to the above-mentioned steps, the detailed wastewater treatment process is provided with several tanks, pumps for chemical preparation dosing and for water transfer.

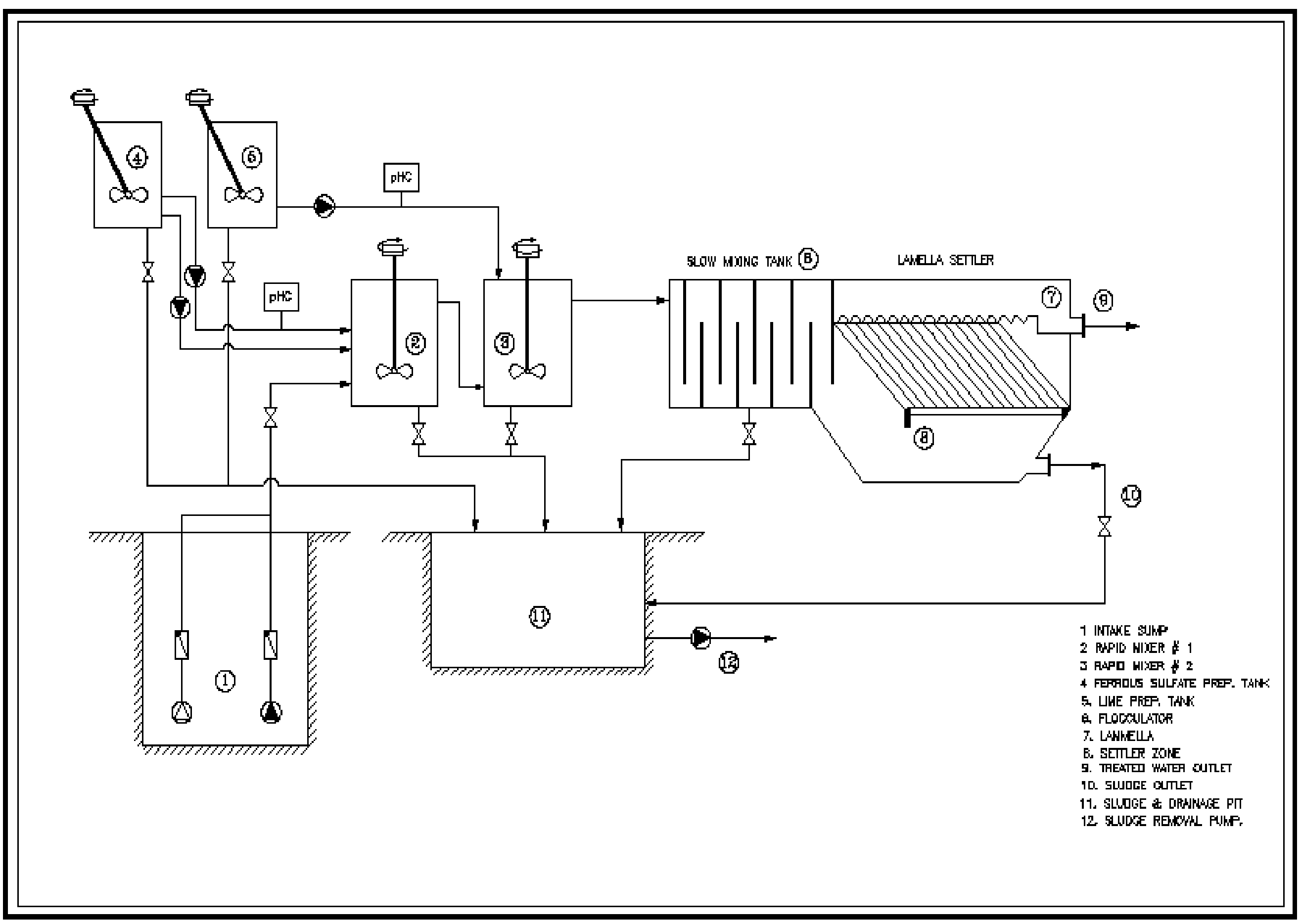

Figure-2. Processes flow diagram of IWWTP

VOL. 15, NO. 23, DECEMBER 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences
©2006-2020 Asian Research Publishing Network (ARPN). All rights reserved.
www.arpnjournals.com

3.3 Lamella Clarifier Design

Based on the experimental study, coagulation as physicochemical wastewater treatment process is recommended. Lamella clarifier is the core of the treatment unit. A detailed design of the clarifier is shown in Figure-3. Figure-3 shows the detailed engineering drawing for the clarifier. As a by-product from the treatment process, sludge is produced from lamella clarifier which can be collected for drying and disposal.

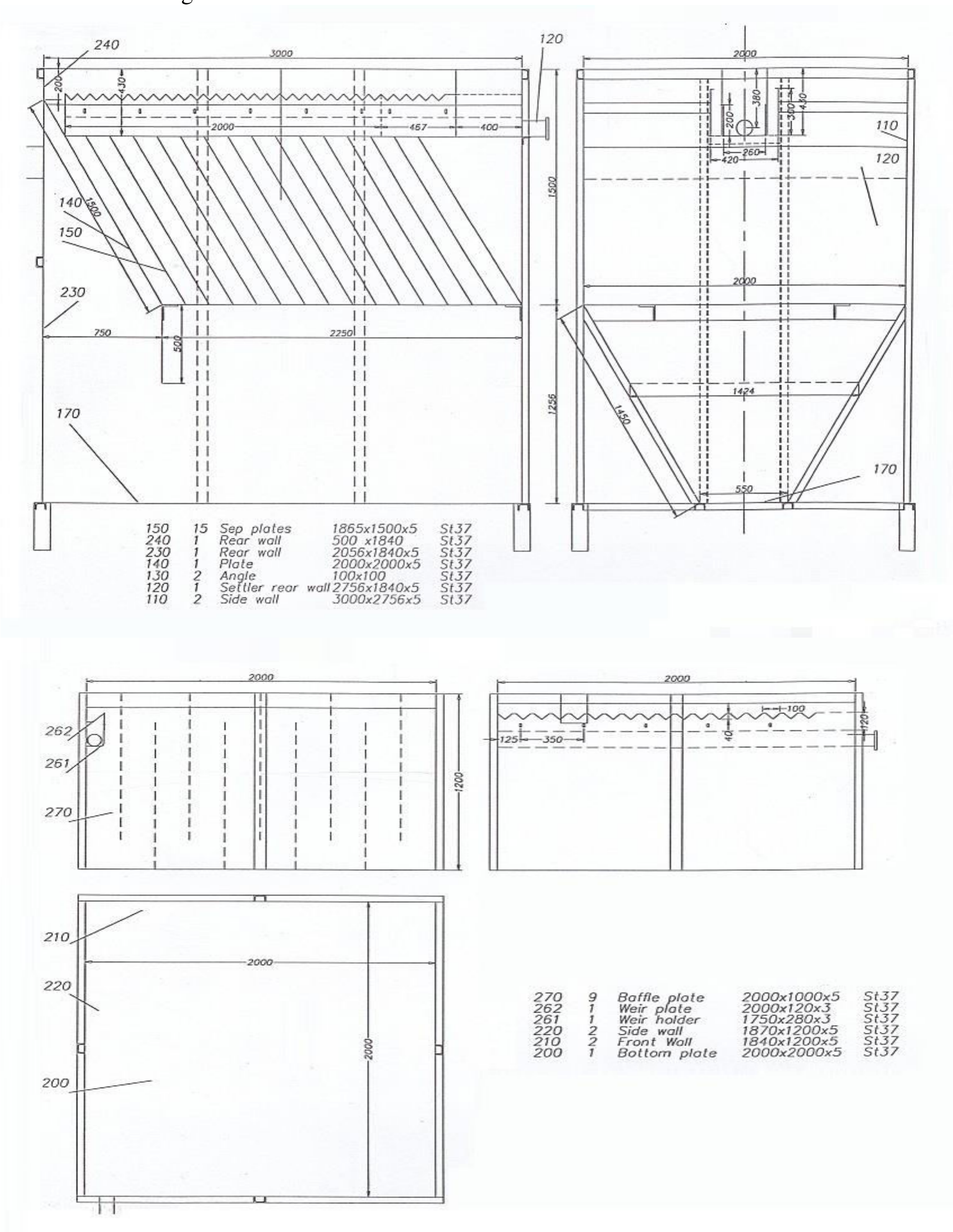

Figure-3. Detailed engineering drawing the Lamella Clarifier

4. CONCLUSIONS

An experimental study was conducted to assess the coagulation process for the treatment of wastewater from a meat processing plant. The experimental study showed that coagulation is an efficient process for reducing pollutant in wastewater to the required permissible limits. Optimum conditions for the coagulation process are flash mixing at 230 rpm for 1 min, flocculation for 15 min at 15 rpm, and a settling time of 1 hour. Maximum removal of organic pollutants was achieved using ferrous sulphate as coagulant and lime for pH adjustment with a dose of 300 and 400 mg/l respectively. COD and BOD_5 removal efficiency was 92 and 95% respectively.

Developed coagulation system showed an efficient treatment of wastewater from meat processing

©2006-2020 Asian Research Publishing Network (ARPN). All rights reserved.

plants. A detailed engineering design for an industrial scale wastewater treatment process is developed and discussed. The proposed design can be implemented in meat processing factories to achieve efficient and economical treatment of wastewater.

ACKNOWLEDGMENT

We wish to express our sincere thanks and gratitude to the Chemical Engineering Department, Faculty of Engineering - Cairo University for providing help in the course of analyses of this investigation.

REFERENCES

[1] Bohdziewicz J., E. Sroka and Korus I. 2003. Application of ultrafiltration and reverse osmosis to the treatment of the wastewater produced by the meat industry. Polish Journal of Environmental Studies. 12(3): 269-274.

[2] Anna Kwarciak-Kozlowska, Jolanta Bohdziewicz, Karolina Mielczarek, Aleksandra Krzywicka. 2011. The Application of UASB Reactor in Meat Industry Wastewater Treatment, Civil, and Environmental Engineering Reports. No. 7.

[3] Naoum Tsolakis, Jagjit Singh Srai and Eirini Aivazidou. 2018. Blue Water Footprint Management in a UK Poultry Supply Chain under Environmental Regulatory Constraints. Sustainability 2018, 10, 625; DOI:10.3390/su10030625.

[4] Ciro Bustillo-Lecompte and Mehrab Mehrvar, Slaughterhouse Wastewater. 2017. Treatment, Management, and Resource Recovery. http://dx.doi.org/10.5772/65499 May.

[5] Chávez P., C., Castillo L., R., Dendooven L. 2005. Poultry slaughter wastewater treatment with an up-flow anaerobic sludge blanket (UASB) reactor, Bioresource Technology. 96(5): 1730-1736.

[6] M. Baskar, Dr. B. Sukumaran. 2015. Effective Method of Treating Wastewater from Meat Processing Industry Using Sequencing Batch Reactor, International Research Journal of Engineering and Technology (IRJET). 2(2).

[7] 2018. The international water association publishing (IWA).

[8] Ibidhi, R.; Hoekstra, A. Y.; Gerbens-Leenes, P. W.; Chouchane H. 2017. Water, land and carbon footprints of sheepand chicken meat produced in Tunisia under different farming systems. Ecol. Indic. 77, 304-312.

[9] Sroka E., Kaminski W. and Bohdziewics J. 2004. Biological treatment of meat industry wastewater, Desalination. 162(10): 85-91.

[10] Jonhs M. R. 1995. Developments in wastewater treatment in the meat processing industry: a review. Bioresource Technology 54, 203-216.

[11] Caixeta C. E. T., Cammarota M. C., Xavier A. M. F. 2002. Slaughterhouse wastewater treatment: evaluation of a new three-phase separation system in a UASB reactor. Bio-resource Technology. 81, 61-69.

[12] Tansengco Myra, Herrera David, Tejano Judith, Yao Marina, Beraye Jose Ricky and Esguerra Reynaldo. 2015. Biological Treatment of Meat Processing Wastewater using Anaerobic Sequencing Batch Reactor (ASBR), International Research Journal of Biological Science. 4(3): 66-75.

[13] Schofield T. 2001. Dissolved air flotation in drinking water production. Water Science and Technology 43(8): 9-18.

[14] Masse D. I. and Masse L. 2000. Treatment of slaughterhouse wastewater in anaerobic sequencing batch reactors, Can. Agr. Eng., 42(3): 131-137.

[15] Masse D. I. and Masse L. 2000. Characterization of wastewater from hog slaughterhouses in Eastern Canada and evaluation of their in-plant wastewater treatment systems, Can. Agr. Eng. 42(3): 139-146.

[16] Ndegwa P. M., Hamilton D. W., Lalman J. A. and Cumba H. J. 2005. Optimization of anaerobic sequencing batch reactors treating dilute swine slurries, Trans. ASAE. 48(4): 1575-1583.

[17] Xiangwen S., Peng D., Teng Z. and Ju X. 2008. Treatment of brewery wastewater using anaerobic sequencing batch reactor (ASBR), Bioresour. Technol. 99(8): 3182-3186.

[18] Pollution Prevention and Abatement Handbook, Meat Processing and Rendering, World Bank Group, Effective July (1998).

[19] Rênnio F. de Sena, Regina F. P. M. Moreira, Humberto J. José. 2008. Comparison of coagulants and coagulation aids for treatment of meat processing wastewater by column flotation, Bioresource Technology. 99, 8221-8225.

©2006-2020 Asian Research Publishing Network (ARPN). All rights reserved.

[20] Sayed S., Van Ampen L., Lettinga L. 1987. Anaerobic treatment of slaughterhouse waste using a granular sludge UASB reactor. Biological Wastes 21, 11-28.

[21] Meyssami B., Kasaeian A. B. 2005. Use of coagulants in treatment of olive oil wastewater model solutions by induced air flotation. Bioresource Technology. 96, 303-307.

[22] De Nardi, I. R., Fuzi, T. P., Del Nery V. 2008. Performance evaluation and operating strategies of dissolved-air flotation system treating poultry slaughterhouse wastewater. Resources Conservation and Recycling. 52, 533-544.

[23] Renault F., Sancey B., Charles J., Morin-Crini N., Badot P.-M., Winterton P., Crini G. 2009. Chitosan flocculation of cardboard-mill secondary biological wastewater. Chem. Eng. J. 155, 775-783.

[24] Mona A. Abdel-Fatah, Marwa M. Elsayed, Gh A. Al Bazedi, S. I. Hawash. 2016. Sewage Water Treatment Plant Using Diffused Air System. Journal of Engineering and Applied Sciences 11(17):10501-10506· 17.

[25] Ahmad, A. L., Ismail, S., Bhatia, S. Optimization of coagulation–flocculation process for palm oil mill effluent using response surface methodology. Environ. Sci. Technol. 39, 2828–2834, (2005).

[26] Mona A. Abdel-Fatah, H. O. Sherif, S. I. Hawash. 2016. Design parameters for waste effluent treatment unit from beverages production. Ain Shams Engineering Journal, Available online 1 June. http://dx.doi.org/10.1016/j.asej.2016.04.008

[27] Tatsi A. A., Zouboulis A. I., Matis K. A., Samaras P. 2003. Coagulation–flocculation pretreatment of sanitary landfill leachates. Chemosphere. 53, 737-744.

[28] Wong S. S., Teng T. T., Ahmad A. L., Zuhairi A., Najafpour G. 2006. Treatment of pulp and paper mill wastewater by polyacrylamide (PAM) in polymer induced flocculation. J. Hazard. Mater. 135, 378-388.

[29] Yue Q. Y., Gao B. Y., Wang Y., Zhang H., Sun X., Wang S. G., Gu R. R. 2008. Synthesis of polyamine flocculants and their potential use in treating dye wastewater. J. Hazard. Mater. 152, 221-227.

[30] Zhong J., Sun X., Wang C. 2003. Treatment of oily wastewater produced from refinery processes using flocculation and ceramic membrane filtration. Sep. Purif. Technol. 32, 93-98.

[31] Chai Siah Lee, John Robinson, Mei Fong Chong. 2014. A review on application of flocculants in wastewater treatment. Process Safety and Environmental Protection. 92, 489-508.

[32] Bratby J. 2006. Coagulation and Flocculation in Water and Wastewater Treatment, 2nd ed. IWA Publishing, London.