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TREATMENT OF POULTRY SLAUGHTERHOUSE WASTEWATER WITH COMBINED SYSTEM

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ABSTRACT
With the interest to reuse and recycle the wastewater for technological use, this project aims to test the treatment of wastewater from poultry slaughterhouse industry from three main sections of the poultry slaughtering process, defeathering, eviscerating and cooling processes. The samples for the project were obtained from Izhevskoe a Kazakhstani company. The technology used is a combination of electrocoagulation, ultrafiltration, and photochemical system and its goal is to provide treated water that can be re-utilized in the poultry industry for sterilization of technical equipment without contaminating and affecting the quality of the poultry products. The treatment of wastewater samples lasted in total for 40 min. From the results, it was found that indicators such as BOD, COD, and phosphates had removal efficiency of almost 100%, while the microbiological colonies were all eradicated from then wastewater making the treated water microbes free. Hence, proving this system to be effective for the treatment of poultry slaughterhouse wastewater and safe for technological reutilization.

Keywords: wastewater; electrocoagulation; ultrafiltration; photochemical

INTRODUCTION
Recently, with the interest in reusing and recycling the wastewater, scientists from across the globe are finding adequate and efficient treatment for poultry slaughterhouse wastewater. Electrocoagulation (EC), ultrafiltration, and photochemical treatment are only some to in the list that are possible methods that could be employed to treat the effluent not only from the poultry slaughterhouse industry but also other industries **(Meiramkulova et al., 2018c)**.

There have been several studies on the effectiveness of wastewater treatment using the EC process that proved it to be effective **(Bayramoglu et al., 2004; Kobya et al., 2003; Can et al., 2003; Lin and Chen, 1997; Meiramkulova et al., 2018a)**. Removal of organic, heavy metals, nutrients, and even pathogens from the wastewater is confirmed to effective is EC is used **(Kobya et al., 2006; Bayar et al., 2011; Meiramkulova et al., 2018d)**. In EC, coagulant ions are discharged into the solution using sacrificial electrodes and current. Reaction at the anode, cathode and consequently solution can be observed from the following reaction **(Picard et al., 2000)**:

$$\text{Anode: } M_s \rightarrow M_{aq}^{n+} + ne^-$$
$$\text{Cathode: } 2H_2O + 2e^- \rightarrow 2OH^- + H_2$$
$$\text{Solution: } M_{aq}^{n+} + nOH^- \rightarrow M(complex) \rightarrow M(OH)_{n(s)}$$

Where M is material of electrodes. Various mono monomeric species such as $M(OH)^{(n-1)}$ and also polymeric species such as $M_6(OH)_{15}^{(6n-15)}$, are formed from metal and hydroxide ions **(Sardari et al., 2018)**. Amorphous $M(OH)_{n(s)}$ in the solution as it ages which can be seen from the reaction above **(Kobya et al., 2003)**.

After that, the metal complexes $M(OH)_{n(s)}$ transforms into solid with a large surface area to trap suspended solids, organic compounds, and form flocs. Finally, the flocs will polymerize, and deposit as can be seen by the following reaction **(Rebhun and Lurie, 1993; Bayramoglu et al., 2004)**.

$$x\, M(OH)_n \rightarrow M_x(OH)_{xn}$$

Membrane technology for the treatment of slaughterhouses wastewater (SWW) is also an alternative with processes such as reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration. These technologies have the ability to remove colloids, particles, and macromolecules depending on the size of the pore **(Spasov and Dinkov, 2002)**. Not only that, there has been a growing use of membrane technology in the removal of microorganism, bacteria, particulates, and organic matter from the SWW. RO and NF are one of the best process that can be used to remove most of the pollutants including dissolved organics. On the other hand, the downside is their high operating cost due to large energy requirements **(Garcia et al., 2013)**. Therefore, UF is a low-pressure and cost-effective option due to its high permeate flux compared to RO and NF. Also, UF is a mature process that has been used in the food processing industry for the past 20 years. There are numerous advantages to UF when compared to conventional treatment methods as it is low energy consuming, no added chemicals, and small footprint **(Sardari et al., 2018)**.

Similar to other membrane process, UF also suffers from membrane fouling. This causes significant decrease in efficiency of water recovery as a result of collected particles both on membrane surface and inside the pores **(Białas et al., 2014)**. Membrane cleaning and pre-treatment are some of the main strategies to minimize fouling. There have been number of studies on membrane cleaning along with sing reagent and multi-step cleaning for fouled membrane **(Mohammad et al., 2012)**. In one study it was shown that moderate flux recovery can be achieved with membrane cleaning and without using pre-treatment **(Malmali et al., 2018)**.

Several pre-treatment process prior to membrane filtration have also been considered. Some of the more popular pre-treatment methods before membrane filtration are pre-oxidation, absorption, pre-filtration, and chemical coagulation. In this study, our focus will be on the utilization of electrocoagulation (EC) as pre-treatment method before UF.

Advanced oxidation processes (AOPs) are also increasingly gaining ground as an alternative to the conventional treatment and as a complimentary treatment (pre-treatment or post-treatment), to processes such as the current biological. Advantage of such technology is that it is able to inactivate microorganism without the need of any chemicals for the treatment of slaughterhouse wastewater. This prevents the usage of method such as chlorination to disinfect the water which can possibly lead to hazardous by-product **(de Sena et al., 2009; Bustillo-Lecompte, Knight and Mehrvar**, **2015)**. Due to this AOPs is recognized as a treatment process that is showing exceptional overall results as a complimentary treatment in water reuse, pollution control, and advanced degradation. One of the most commonly used AOPs is the UV/H_2O_2 process. This method is found to be effective for the treatment of SWW. From the reaction of UV and H_2O_2, hydroxide radicals (OH) are produced which oxidizes and degrades the effluents, making this technology effective **(Bustillo-Lecompte, Knight and Mehrvar**, **2015)**. However, in this study since EC and UF are already being utilized as a treatment technology, only UV radiation will be used as a post-treatment to inactivate microorganism present is the water after the UF process.

In this study, investigation of the effectiveness of poultry slaughterhouse wastewater (PSW) treatment using a combined system of EC, UF, and UV sterilization will be analysed. This system is intended for recycling and reusing the wastewater that can ease the burden on water fresh resources and at the same time not affect the quality of the sterilization of the equipment used for the slaughtering processes. Also, since there are not many studies done on the combination of EC-UF-UV for PSW treatment, this research can provide a base for other future studies in this area.

Scientific hypothesis

The designed combined poultry slaughterhouse wastewater treatment system involving sedimentation, EC process, ultrafiltration, and UV treatment will show exceptional results as removal efficiencies for almost all indicators are within the quality standards. Also, the wastewater after treatment will be 100% free from microbe colonies. The technology is proposed for obtaining technical water from the wastewater with antioxidant properties for washing and disinfecting equipment and premises of poultry farms, not affecting the quality of poultry products (important for food safety standards **(Nagyová et al., 2019)**). The project will reduce the volume of water consumption of the poultry industry, which is one of the important indicators of "green technology".

MATERIAL AND METHODOLOGY

Water Characteristics

Table 1 below shows the characteristic of wastewater obtained from Izhevskoe a Kazakhstani company. The sample is from cooling section and was kept at 4 ℃ once delivered to the lab. To examine characteristics of the wastewater, analytical methods were used which are described in the following section. Also, before conducting the experiment, calcium chloride was added to the wastewater for the EC process.

Experimental apparatus and procedure

In this study, a combined system is used which comprises of EC process, ultrafiltration, and photochemical purification. Figure depicts the schematic of the lab combined system used. First, the mini reservoir collects the wastewater and filters large particles such as feathers or organic components, using the macro-filter added. The effluent then leaves the reservoir and enter the electrolyte cell in which the EC process occurs for about 30 min. This electrolyte cell is made from polypropylene material with the dimensions 15 x 13 x 11 cm. The electrodes plate dimension used were 10.5 x 11.5 x 0.2 cm and 10.5 x 10.5 x 0.8 cm for aluminium (anode) and graphite (cathode) electrodes respectively. These electrodes were connected to direct current supply (Xinhua electrical weld company, China) characterized by the ranges 0 – 10 A for operating current and 0 – 12 V for voltage. Usually, electrodes selected are iron and aluminium as they are cheap and readily available. However, in our previous study, we have mentioned that using graphite is a better option as it is inert and does not consumes, making it not only efficient but also cost-effective **(Meiramkulova et al., 2018d)**.

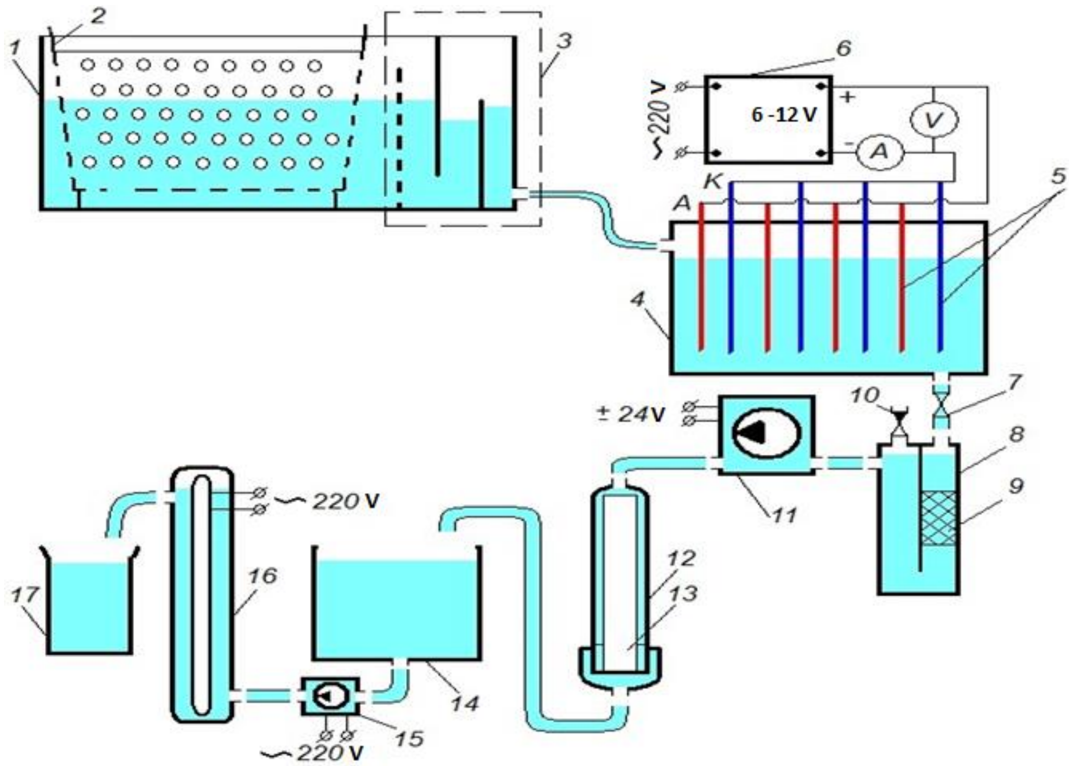

Figure 1 Combined poultry slaughterhouse wastewater treatment system.
Note: 1 – Wastewater Reservoir; 2 – Removable Macro-filter; 3 – Oil collection; 4 – Electrolyte cell; 5 – Electrodes (A – anode, K – cathode); 6 – Power supply; 7 – Valve; 8 – Sedimentary cylinder; 9 – Filter; 10 – Air vent valve; 11 – Pump (Maximum pressure of 5.5bar); 12 – Ultra-filter; 13 – Ultra-filtration membrane; 14 – Reservoir; 15 – Circulatory pump; 16 – Ultraviolet lamp; 17 – Reservoir for pure water.

Once EC is completed, processed water is then transferred to the sedimentary cylinder where any organic matter is collected. A pump with a pressure of up to 5.5 bar, allows the water to flow from the sedimentary cylinder to the ultrafilter. This ultrafilter has a pore size of 0.02 µm, sufficient to trap most sediments, bacteria, and viruses. Finally, the ultra-filtered water flows to a small reservoir where a small pump is used to recirculate the water through an UV sterilizer for 10 min to kill any remaining microorganism in the water. Overall, this process lasted for about 40 min.

Mechanism of ion transformation during EC

Calcium chloride was added as an electrolyte to all samples before electrolysis, which decreases pH level of the wastewater and prevent basic condition from occurring which can lead to formation of ammonia gas that can be harmful to the environment. Furthermore, the formation of hypochlorite ions occurs during the EC process. Then, at anode molecular chlorine consequently hydrolyses in neutral water condition, hence, reducing its concentration **(Czarnetzki and Janssen, 1992)**.

$$2Cl^- - 2e^- \rightarrow Cl_2$$
$$Cl_2 + H_2O \rightarrow HClO + H^+ + Cl^-$$

Phosphorus compounds present in the PSW are represented as polyphosphates, orthophosphates, and organic phosphorus-containing compounds. They can be present in the form of dissolved, colloidal and suspended state as phosphate ions. During EC treatment, phosphate ions released combine with a metal ion to produce metal phosphates, reducing the total phosphate presence in the treated water **(Emerson and Widmer, 1978)**.

As for nitrogen containing compounds, urea is a main by-product of the organisms. It can be found in animal-based industrial wastewater as ammonium carbonate under the impact of putrefying bacteria **(Barmaki et al., 2009)**.

$$CO(NH_2)_2 + 2H_2O \rightarrow (NH_4)_2CO_3$$

However, it degrades and results in carbon dioxide and ammonia.

$$(NH_4)_2CO_3 \rightarrow 2NH_3 + CO_2 + H_2O$$

Ammonia then transforms into nitrite and nitrate ions by consuming oxygen under the impact of nitrifying bacteria as it is shown below **(Pan et al., 2018)**.

Nitrification:

1-step $\quad NH_4^+ + 2O_2 \rightarrow NO_2^- + H_2O + H^+$

2-step $\quad NO_2^- + 0.5O_2 \rightarrow NO_3^- + H_2O + H^+$

Then nitrate ions combine with metal ions. Thereby, nitrates are neutralized, again reducing its concentration in the treated water.

Table 1 Poultry slaughterhouse wastewater characteristic before treatment.

Indicators	Defeathering	Evisceration	Cooling	Units
pH	7.36	7.2	6.5	-
Turbidity	49.7	98.5	167	FAU
Color	649	1371	1762	
TSS	84	180	298	$mg.L^{-1}$
Chlorine free	0.14	0.03	0.80	$mg.L^{-1}$
Chlorine total	0.11	0.07	6.57	$mg.L^{-1}$
Nitrogen nitrites	0.109	0.06	0.122	$mg.L^{-1}$
Nitrogen nitrates	18.5	8.30	24.5	$mg.L^{-1}$
Phosphates	5.00	5.06	1.79	$mg.L^{-1}$
Nitrogen ammonium	1.28	2.27	0	$mg.L^{-1}$
COD	578	1162	1729	$mg.L^{-1}$
BOD5	96.2	12.1	458.8	$mg.L^{-1}$
Carbonates	0	90	0	$mg.L^{-1}$
Hydrocarbonates	488	457,6	427	$mg.L^{-1}$
Calcium	14	23.5	11	$mg.L^{-1}$
Magnesium	2	16.5	26.5	$mg.L^{-1}$

Furthermore, ammonia reacts with hypochlorite ions and produces monochloramine and dichloramine in acidic condition **(Asano et al., 2005)**. Later, mono and dichloramines results in nitrogen gas.

$$NH_3 + HClO \rightarrow NH_2Cl + H_2O$$
$$NH_2Cl + HClO \rightarrow NHCl_2 + H_2O$$
$$NH_2Cl + NHCl_2 \rightarrow N_2 + 3HCl$$

All these reactions allow the reduction of pollutants in the wastewater.

Statistic analysis

The data obtained for the pollutant level in the poultry slaughterhouse wastewater was measured locally within the university lab. The following equipment was used in the measurements of the pollutant concentration: Standard Operating Procedure for GLNPO Turbidity: Nephelometric Method and American Public Health Association 4500-Nor, were used to determine the turbidity of the samples, and total bound nitrogen (TN) and total phosphorus (TP) respectively. Spectrophotometer (Hach DR3900, HACH / LANGE, Germany), standard reagents and test kits were used for the reliability of the chemical analysis. Furthermore, lab pH-meter (Hach Co), was used to measure pH values.

In accordance with the regulatory requirements of industrial and drinking water of the Republic of Kazakhstan, sanitary and microbiological examination of water before and after treatment was done based on 3 indicators:

- Total microbial count (TBC) is an indicator for assessing total bacterial contamination.
- Total coliform bacteria (TCB) are conditionally distinguished by morphological and cultural characteristics of a group of bacteria of the *Enterobacteriaceae* family, used by sanitary microbiology as a marker of fecal contamination, belong to the group of so-called sanitary-indicative microorganisms.
- Thermotolerant coliform bacteria (TTCB) is a group of coliform organisms capable of fermenting lactose at 44 – 45 °C.

The calculation was performed through:

$$x = \frac{a * 100}{V}$$

x - number of colonies per 100 mL;
V - filtered volume of water;
a - total number of colonies counted on filters.

For the processing of the microbiological data of water before and after combined cleaning from defeathering, evisceration, cooling sections a statistical analysis Wilcoxon T-test was carried out (n = 8). This study suggested a hypothesis H_0: indicators after the experiment is less than the values of the indicators before the experiment; H_1 indicators after the treatment more than the values before the experiment.

The critical values for the Wilcoxon T-test for n = 8:
T_{cr}=1(p ≤0.01)
T_{cr}=5 (p ≤0.05)
In this case, the empirical value of T falls into the zone of significance: $T_{emp} < T_{cr}$.
Hypothesis H_0 is accepted for all sections.

RESULTS AND DISCUSSION

The results obtained (Table 2) from the analysis proved to be impressive as the pollutant level of most indicators in the wastewater decreased by more than 90%. It is worth noting that the pH level decreased in the treated water which helped to reduce the concentration of the pollutants. The acidic condition formed from the addition of calcium chloride helped to allow the chemical reactions described above during the EC process to take place. Other studies also proved that the initial decrease in pH value during the EC process is beneficial for the pollutant removal, hence improving the overall removal efficiency.

Table 2 Poultry slaughterhouse wastewater characteristic after treatment.

Indicators	Defeathering	Evisceration	Cooling	Units
pH	6.5	6.3	5.9	-
Turbidity	-4.53	0.469	-3.80	FAU
Color	13	71.0	53	
TSS	1.0	10.0	3.0	mg.L-1
Chlorine free	0.02	0.29	0,01	mg.L-1
Chlorine total	0.12	0.27	0.51	mg.L-1
Nitrogen nitrites	0.09	0.95	1.18	mg.L-1
Nitrogen nitrates	1.74	2.42	1.25	mg.L-1
Phosphates	11.2	51.3	20.5	mg.L-1
Nitrogen ammonium	2.7	7.5	4.3	mg.L-1
COD	18.5	1.1	2.8	mg.L-1
BOD5	0.022	0.051	0.065	mg.L-1
Carbonates	0	0	0	mg.L-1
Hydrocarbonates	91.5	91.5	152.5	mg.L-1
Calcium	11	14	10.5	mg.L-1
Magnesium	9	10	14.5	mg.L-1

Table 3 Removal efficiency from chemical pollution of treated water

Sections	Defeathering	Evisceration	Cooling	*p*-value
TSS	98.8%	94%	99.0%	≤0.05
N nitrates	90.6%	71%	94.9%	≤0.05
BOD_5	100.0%	100%	100.0%	≤0.01
COD	96.8%	100%	99.8%	≤0.05

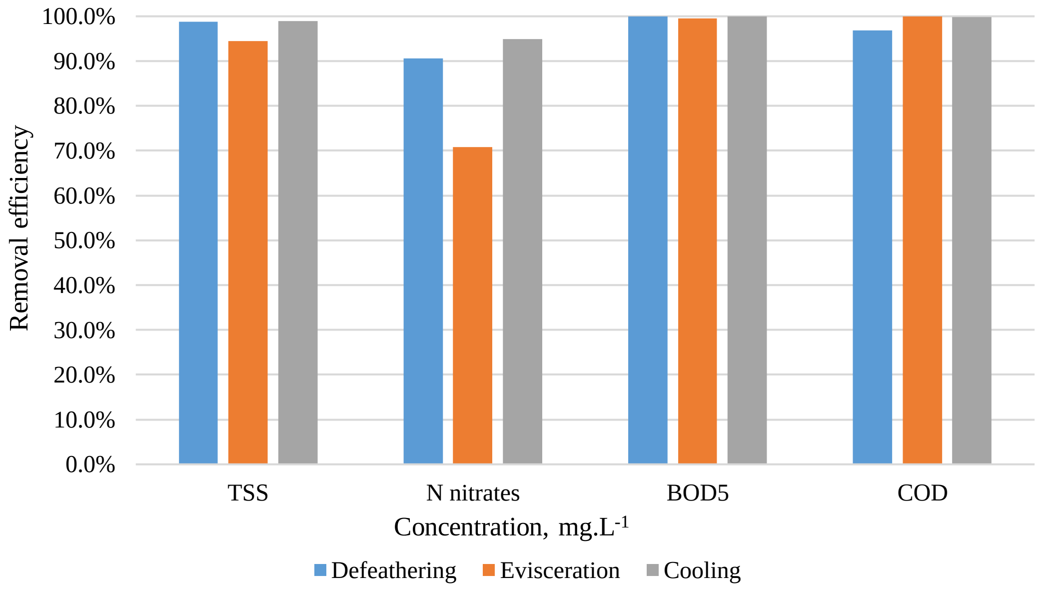

Figure 2 Chemical results for combined system.

It can be seen from the figure below that for all sections from which the wastewater was treated, the removal efficiency of COD, BOD, phosphates, TSS and nitrogen nitrates were close to 100%. Only chloride and nitrogen nitrite removal efficiency were about 80% or more. Overall, from the chemical analysis results (Table 2) it can be seen that this system is effective and can provide a technologically safe purified water. Also, from Table 3 it can be seen that the *p*-values of some indicators from the chemical pollutant analysis after treatment is ≤0.05, proving our H_0 hypothesis.

The microbiological results obtained after treatment showed that the microbiological colonies had a removal efficiency of 100%, making the water safe and hence not affecting the quality of poultry products. This again shows that the system is overall efficient **(Meiramkulova et al., 2018b)**. Once again, the H_0 hypothesis is valid as the microbes are eradicated from the treated water after treatment and the *p*-value is ≤0.01.

Observing both the chemical and microbiological results, it can be seen that this system is effective as it not only has high removal efficiency for chemical indicators, but also eradicates all microbiological colonies present in the

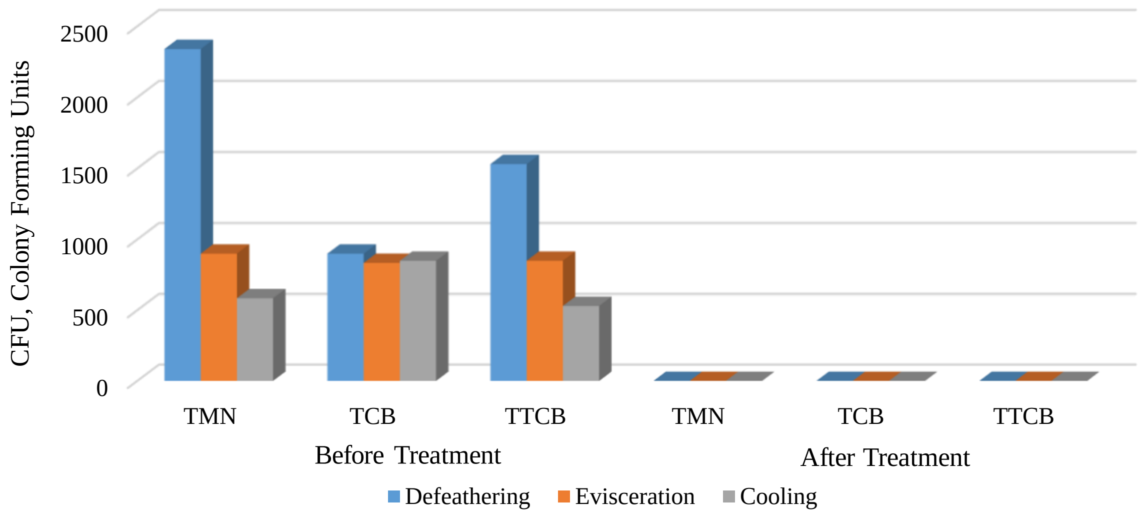

Figure 3 Microbiological results.

wastewater before treatment, making it safe to use for technological purposes within the poultry industry. Also, from the statistical analysis the indicators after the experiment do not exceed the values of the indicators before the experiment.

CONCLUSION

This project aim was to recycle poultry slaughterhouse wastewater for technological use. The results obtained for the combined system showed exceptional results. The removal rate of more than 90% of most pollutants was observed from the chemical analysis and microorganism colonies were all eliminated after treatment, the results of the microbiological analysis showed 100% efficiency of complex water purification, proving the treated water to be safe for technological use within the poultry industry. Also, the use of aluminium and graphite electrode combination proved to be effective during the EC process. For future works on this system, different electrode combination can be used to find a more effective method of treatment.

REFERENCES

Asano, M., Nakamura, K., Katou, Y., Mizutani, H., Ike, T. 2005. Decomposition System of Nitrogen Compounds in Waste Water with Electrolysis. *Mitsubishi Heavy Industries, Ltd. Technical Review*, vol. 42, no. 4, p. 1-4.

Barmaki, M., Rahimpour, M., Jahanmiri, A. 2009. Treatment of wastewater polluted with urea by counter-current thermal hydrolysis in an industrial urea plant. *Separation and Purification Technology*, vol. 66, no. 3, p. 492-503. https://doi.org/10.1016/j.seppur.2009.02.007

Bayar, S., Yildiz, Y. S., Yilmaz, A. E., Irdemez, S. 2011. The effect of stirring speed and current density on removal efficiency of poultry slaughterhouse wastewater by electrocoagulation method. *Desalination 280*, vol. 1, no. 3, p. 103-107. https://doi.org/10.1016/j.desal.2011.06.061

Bayramoglu, M., Kobya, M., Can, O., Sozbir, M. 2004. Operating cost analysis of electrocoagulation of textile dye wastewater. *Separation and Purification Technology*, vol. 37, no. 2, p. 117-125. https://doi.org/10.1016/j.seppur.2003.09.002

Białas, W., Stangierski, J., Konieczny, P. 2014. Protein and water recovery from poultry processing wastewater integrating microfiltration, ultrafiltration and vacuum membrane distillation. *International Journal Of Environmental Science and Technology*, vol. 12, no. 6, p. 1875-1888. https://doi.org/10.1007/s13762-014-0557-4

Bustillo-Lecompte, C., Knight, M., Mehrvar, M. 2015. Assessing the performance of uv/H_2O_2 as a pretreatment process in TOC removal of an actual petroleum refinery wastewater and its inhibitory effects on activated sludge. *The Canadian Journal of Chemical Engineering*, vol. 93, no. 5, p. 798-807. https://doi.org/10.1002/cjce.22180

Can, O., Bayramoglu, M., Kobya, M. 2003. Decolorization of Reactive Dye Solutions by Electrocoagulation Using Aluminum Electrodes. *Industrial & Engineering Chemistry Research*, vol. 42, no. 14, p. 3391-3396. https://doi.org/10.1021/ie020951g

Czarnetzki, L., Janssen, L. 1992. Formation of hypochlorite, chlorate and oxygen during NaCl electrolysis from alkaline solutions at an RuO_2/TiO_2 anode. *Journal of Applied Electrochemistry*, vol. 22, no. 4, p. 315-324. https://doi.org/10.1007/bf01092683

de Sena, R., Tambosi, J., Genena, A., Moreira, R., Schröder, H., José, H. 2009. Treatment of meat industry wastewater using dissolved air flotation and advanced oxidation processes monitored by GC–MS and LC–MS. *Chemical Engineering Journal*, vol. 152, no. 1, p. 151-157. https://doi.org/10.1016/j.cej.2009.04.021

Emerson, S., Widmer, G. 1978. Early diagenesis in anaerobic lake sediments - II. Thermodynamic and kinetic factors controlling the formation of iron phosphate. *Geochimica Et Cosmochimica Acta*, vol. 42, no. 9, p. 1307-1316. https://doi.org/10.1016/0016-7037(78)90035-2

Garcia, N., Moreno, J., Cartmell, E., Rodriguez-Roda, I., Judd, S. 2013. The cost and performance of an MF-RO/NF plant for trace metal removal. *Desalination*, vol. 309, p. 181-186. https://doi.org/10.1016/j.desal.2012.10.017

Kobya, M., Can, O., Bayramoglu, M. 2003. Treatment of textile wastewaters by electrocoagulation using iron and aluminum electrodes. *Journal of Hazardous Materials*, vol. 100, no. 1-3, p. 163-178. https://doi.org/10.1016/s0304-3894(03)00102-x

Kobya, M., Senturk, E., Bayramoglu, M. 2006. Treatment of poultry slaughterhouse wastewaters by electrocoagulation. *J. Hazard. Mater.*, vol. 133, no. 1-3, p. 172-176. https://doi.org/10.1016/j.jhazmat.2005.10.007

Lin, S., Chen, M. 1997. Treatment of textile wastewater by chemical methods for reuse. *Water Research*, vol. 31, no. 4, p. 868-876. https://doi.org/10.1016/s0043-1354(96)00318-1

Malmali, M., Askegaard, J., Sardari, K., Eswaranandam, S., Sengupta, A., Wickramasinghe, S. 2018. Evaluation of ultrafiltration membranes for treating poultry processing wastewater. *Journal of Water Process Engineering*, vol. 22, p. 218-226. https://doi.org/10.1016/j.jwpe.2018.02.010

Meiramkulova, K., Aubakirova, K., Userbayev, M., Sayabayev, K. 2018a. Эффективность очистки сточных вод убойного цеха птицефабрики электрохимическим методом (Efficiency of wastewater treatment at the slaughterhouse of the poultry farm using the electrochemical method). *Известия международной академии аграрного образования (News of the International Academy of Agrarian Education)*, vol. 42, no. 2, p. 55-60. (In Russian)

Meiramkulova, K., Sagyndykov, U., Aubakirova, K., Temirbekova, A. 2018b. Исследование обсеменённости вод микроорганизмами путём фотохимической очистки (The study of the contamination of water by microorganisms by photochemical purification). *Информационные технологии, системы и приборы АПК, материалы 7-й Международной научно-практической конференции «Агроинфо-2018». Сибирский Федеральный научный центр агробиотехнологий (Information technologies, systems and devices of the agro-industrial complex, materials of the 7th International Scientific and Practical Conference "Agroinfo-2018". Siberian Federal Research Center for Agrobiotechnology)*, p. 325-328. (In Russian)

Meiramkulova, K., Tolysbayev, B., Kydyrbekov, S., Rink, I., Tsoy, A., Lyubimov, E., Mishurov, P. 2018c. Экологическая оценка водопользования птицефабрик Республики Казахстан (Environmental assessment of water use in poultry farms of the Republic of Kazakhstan). *Техника и оборудование для села (Equipment and facilities for the village)*, vol. 12, no. 258, p. 30-34. (In Russian)

Meiramkulova, K., Userbayev, M., Aubakirova, K., Saiyabayev, K., Suleimenova, B. 2018d. Electrochemical treatment of poultry industry wastewater. *International Journal of Mechanical Engineering and Technology*, vol. 9, no. 10, p. 1285-1293.

Mohammad, A., Ng, C., Lim, Y., Ng, G. 2012. Ultrafiltration in Food Processing Industry: Review on Application, Membrane Fouling, and Fouling Control. *Food and Bioprocess Technology*, vol. 5, no. 4, p. 1143-1156. https://10.1007/s11947-012-0806-9

Nagyová, Ľ., Andocsová, A., Géci, A., Zajác, P., Palkoič, J., Koščiarová, I., Golian, J. 2019. Consumers´ awareness of food safety. *Potravinarstvo Slovak Journal Of Food Sciences*, vol 13, no. 1, p. 8-17. https://doi.org/10.5219/1003

Pan, K., Gao, J., Fan, X., Li, D., Dai, H. 2018. The more important role of archaea than bacteria in nitrification of wastewater treatment plants in cold season despite their numerical relationships. *Water Research*, vol. 145, p. 552-561. https://10.1016/j.watres.2018.08.066

Picard, T., Cathalifaud-Feuillade, G., Mazet, M., Vandensteendam, C. 2000. Cathodic dissolution in the electrocoagulation process using aluminium electrodes. *Journal of Environmental Monitoring*, vol. 2, no. 1, p. 77-80. https://10.1039/a908248d

Rebhun, M., Lurie, M. 1993. Control of Organic Matter by Coagulation and Floc Separation. *Water Science and Technology*, vol. 27, no. 11, p. 1-20. https://doi.org/10.2166/wst.1993.0260

Sardari, K., Fyfe, P., Lincicome, D., Wickramasinghe, S. 2018. Aluminum electrocoagulation followed by forward osmosis for treating hydraulic fracturing produced waters. *Desalination*, vol. 428, p. 172-181. https://doi.org/10.1016/j.desal.2017.11.030

Spasov, H., Dinkov, K. 2002. Removing of infecting microorganisms during wine production trrough membrane filtration. *Bulgarian Journal of Agricultural Science*, vol. 8, p. 581-586.

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