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Feather-Processing Wastewater: Composition, Influence on the Natural Water Objects and Decontamination Technologies

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Summary

Poultry farming and production is one of very important branches of the food and food processing industry, which produces important foodstuffs, semi-finished products and by-products for further processing. Intense processing of the poultry products results in a massive formation of the heavily polluted wastewaters containing many hazardous pollutants. This problem is very acute for many countries where this branch is quick-growing and being under extended investigation of various decontamination methods of the poultry processing wastewaters. Poultry feather is not involved in any food processing industry but can be used as an adsorbent or filler for some clothes and bed clothes. Relevant industrial feather-processing stages also produce some contaminated wastewaters and a problem of their decontamination is still beyond systematic analysis and investigation. This paper deals with analysis of the poultry feather-processing wastewaters composition and experimental investigation of various methods and technologies of their decontamination. Iron chloride combined with polyacrylamide ensured the best wastewater cleaning/flocculation activity and a combined wastewater treatment scheme with primary cleaning/flocculation, secondary complex biotreatment and tertiary sand-filtration has been proposed in order to reach a required decontamination depth. This technology proves the wastewater quality, which complies with the officially set limits.

Keywords: feather-processing wastewater; organic pollution; wastewater treatment technology

Introduction

Poultry farming industry is one of the leading branches of the foodstuffs production in many developed and developing countries. Poultry grows very fast and can supply a significant part of the nutritional needs. The poultry meat processing industry responds to the growing demand in its products with extended output and intensified technologies. An average output of the typical poultry production plant has grown five times since the 60s (Kiepper, 2003). Moreover, traditionally the plant produced mostly whole birds while now it produces a mix of whole birds, cut-up meat and other products along with some semi-finished and side products (Ollinger et al, 2000). Chicken meat annual consumption in the USA is constantly growing since 50s and has reached about 28 kg per capita in the mid-2000s while it was only about 6.5 kg in the 1950s (Kiepper, 2003, US Dept. of Agriculture Report, 2010). Similar tendency of the growing consumption of the poultry meat has been reported for Hong Cong, UK, Netherlands, Poland and some other countries (Per Capita Consumption of Meat and Poultry by Country, 2000). As output of the poultry industry is rising, simultaneous growth of the wastes and wastewaters formation is unavoidable. Various issues related to the waste materials utilization and decontamination of the wastewaters are being thoroughly investigated and a quality of the wastewaters discharged by the poultry slaughter and processing factories is under strict monitoring (Marcinkowski T. A, 2010).

Poultry feather is one of by-products produced by the poultry industry. Some part of this material can be utilized as an adsorbent for removal of the toxic inorganic and organic compounds (Mittal A, 2006, Sun P et al, 2009). Source of keratin for the artificial fiber is another use of the feather (Schmidt W. F, 1998, McGovern V, 2000). However, most part of the poultry feather is traditionally used as a source material for manufacturing of various pillows, blankets and feather-stuffed clothes. The latter application is realized at special feather-processing factories, which also discharge own wastewaters and can seriously contaminate natural water objects.

This work deals with an analysis of composition of the feather-processing factory wastewaters discharged by the joint venture “Billerbeck” of Chortkiv (Ukraine) and investigation of efficiency of the proposed wastewater treatment solutions. Approximate daily volume of the factory’s wastewaters to be treated is 65 m^3. The factory’s wastewater used to be sent to the nearby wastewater treatment station, which collected water from several nearby industrial objects. However, the mother plant has been closed down because of bankruptcy and no wastewater treatment is currently provided. Factory’s wastewaters are being discharged with practically no treatment and cause over-normative contamination of the river water.

The factory produces various feather-downy goods: carpets, blankets and mattresses and uses raw poultry feather as a source material. The feather treatment technology consists of the following stages: collection, preliminary dewatering, washing and drying. Two groups of pollutants can be found in the industrial wastewaters: washed-off natural components of the feather – feather fragments and grease (1) and surfactants used for better cleaning of the feather (2). As a result, the wastewater composition is quite complex and includes colloid pollutants (clay-like and humic particles, keratin destruction products), molecular (surfactants, other organic compounds, albumens) and ionic (inorganic salts) substances. Although these

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pollutants seem less dangerous than the compounds found in the wastewater of the poultry slaughtering plants, uncontrolled discharge of the feather-processing wastewaters can also cause significant worsening of the water quality in an intake water object. Natural decomposition of the compounds present in feather-processing wastewaters causes bad odor of the water, formation of foam, which intensively absorbs pollutants and pathogenic microbes. Water transparency and normal gas exchange with the air are also adversely affected by the foam. All these processes provoke stagnation of water while nitrogen- and phosphorus-containing compounds promote active euthrophication. This results in a growing disbalance between the biomass formation and decomposition and seriously disturbs ecological conditions of the water body (Korte F, 1997).

Experimental

Contents of the following pollutants or groups of pollutants and water quality parameters have been determined in the raw wastewater and after its treatment using various agents and technologies: pH, COD, contents of the ether-soluble grease, surfactants and suspended particles. Aluminium sulfate and iron(III) chloride were tested as coagulants, AN 913 SH (0.1 % solution of polyacrylamide (PAA)) – as flocculant. Sodium hydroxide, technical lime or a mixture of these compounds were added to some samples for alkalization in order to bring an after-treatment pH to the close-to-neutral value. The choice of these compounds grounds on the obvious requirement to use rather well-known and inexpensive reagents and equipment to ensure needful depth of the wastewater treatment. The factory's wastewaters are being discharged to the low-water river of Seret, which is considered as an object with the fish-farming water quality. Therefore, the treated wastewater should meet very strict requirements imposed on its quality.

All results of the raw and treated wastewater samples analyses are shown in Table 1. Water quality parameters were determined according to the standard certified methods (Lourie Yu, 1984). It is seen that combined treatment of the wastewater with $FeCl_3$ and AN 913 SH ensures the best results. On the other hand, treatment with this mixture does not produce excessive acidification of the samples (as $Al_2(SO_4)_3$-based compositions) and should not be followed by alkalization.

Aeration has been proposed to speed up the physicochemical treatment in this stage. This method ensures quick formation of the massive foam, which intensively captures significant part of the pollution (especially suspended particles) just in the beginning of aeration. Then this layer can be easily separated from the rest of wastewater and frothed down at the end of this stage. Rest of the wastewater can be filtrated. So, this combined physicochemical cleaning method seems more efficient than a simple settling and can be recommended as the first stage in the feather-processing wastewaters treatment scheme.

However, this technology does not ensure required cleaning and wastewater quality remains too low after this stage (see Table 2). For instance, a content of surfactants is still too high and can not be lowered to the limit values in the control point (500 m downriver from the discharge point) even after discharge and dilution with river water. Concentration of the grease compounds is also too high.

The secondary biotreatment is proposed to be employed after the preliminary coagulation/flotation in order to reach appropriate concentrations of the pollutants. An intense biodecontamination starts in the aerated water just in the flotation tank and continues at this stage resulting further lowering in the pollutants concentration. However, secondary aeration and another biotreatment should be used for better decomposition of the

Table 1. *Water quality parameters of raw wastewater and samples after coagulation and coagulation/flocculation treatment**

Water quality parameters	Raw untreated wastewater	Wastewater after treatment						
		$Al_2(SO_4)_3$	$Al_2(SO_4)_3$ + NaOH	$Al_2(SO_4)_3$ + $Ca(OH)_2$	$FeCl_3$	$FeCl_3$ + $Al_2(SO_4)_3$	$Al_2(SO_4)_3$ + AN 913 SH	**$FeCl_3$ + AN 913 SH**
COD (mg/l)	1600.0	272.0	304.0	272.0	256.0	310.0	306.0	**224.0**
Grease (ether-soluble) (mg/l)	362.0	60.0	62.1	58.0	48.0	72.2	72.0	**36.0**
Surfactants (mg/l)	38.6	11.8	12.0	10.0	8.0	16.0	10.0	**8.0**
pH	6.8	6.9	7.45	7.8	6.8	6.8	6.9	**6.8**
Suspended particles (mg/l)	372	44.0	56.0	42.3	38.0	48.0	46.0	**32.0**

** - concentrations of the coagulants and flocculants (mg/l): $Al_2(SO_4)_3$ – 5; $Al_2(SO_4)_3$ + NaOH – 5+5; $Al_2(SO_4)_3$ + $Ca(OH)_2$ – 5+5; $FeCl_3$ – 5; $FeCl_3$ + $Al_2(SO_4)_3$ – 2.5+2.5; $Al_2(SO_4)_3$ + AN 913 SH – 5+0.1; $FeCl_3$ + AN 913 SH – 5+0.1.*

Table 2. *Quality parameters for untreated and treated wastewater after various stages*

Water quality parameters	Raw untreated wastewater	After stage I (coagulation + flocculation)	After stage II (primary & secondary biotreatment)	After stage III (sand flitration)
COD, mg/l	1600.0	224.0	80.0	60.0
Grease (ether-soluble), mg/l	362.0	36.0	5.0	2
Surfactants, mg/l	38.6	8.0	0.5	0.1
pH	6.8	6.8	6.8	6.8
Suspended particles, mg/l	372.0	32.0	15.0	10 – 12
NH_4^+, mg/l	38.7	7.0	2.0	1.0
Phosphates, mg/l	5.3	3.2	1.0	0.17

organic compounds remained after previous stage. An excessive activated sludge (EAS) is growing during the biotreatment and should be removed before piping the wastewater out from this stage. The sludge and sediment retain significant amounts of the pollutants and products of their bio-decomposition and should be carefully separated from the water.

Capturing of small particles and floccules of the pollutants, which slipped through previous filtration equipment is ensured at the final wastewaters filtration with the sand filters. Then outgoing wastewater quality can be analyzed for conformity with the limit values achieved in the control point. All quality parameters of the wastewater after three stages of the treatment are summarized in Table 2.

Results and Discussions

One can see that this scheme ensures a dramatic content lowering for the most dangerous and unwanted organic pollution agents: output concentration of grease is 180 times lower than the incoming and surfactants – 386 times lower. It is necessary to emphasize that surfactants are hardly removable and can be considered as persistent water pollution agents. Such significant drop in this concentration is a clear evidence of efficiency of the proposed scheme. A wastewater treatment technology has been embodied in the following scheme.

Final evaluation of the wastewater treatment efficiency should take into consideration dilution of the discharged waste-

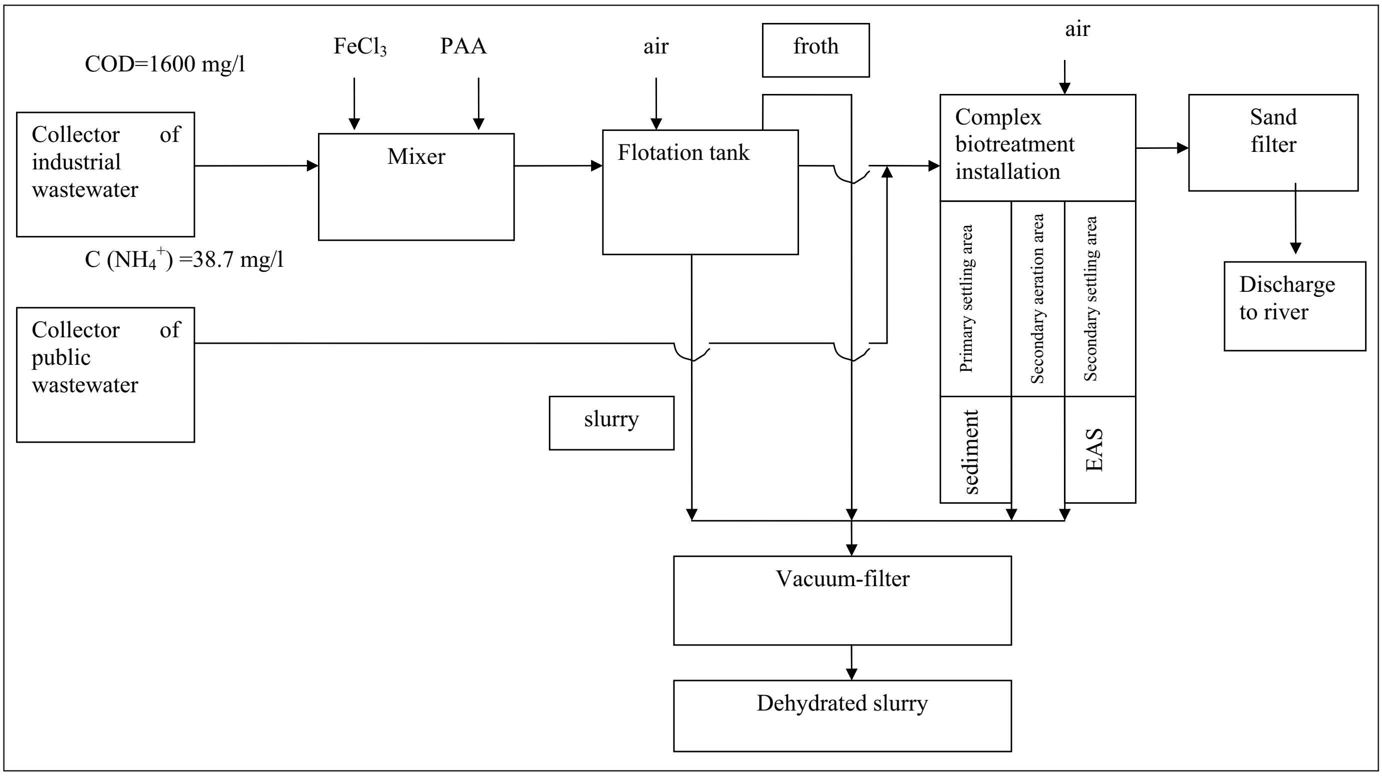

Figure 1. *A technological flowchart of the proposed technology of the wastewaters treatment*

Table 3. *Quality of the wastewater and calculated concentrations of pollutants in the control point*

Wastewater quality parameters	Threshold contents for the fish-farming water, mg/l	Background concentrations in the river Seret, mg/l	Actual concentrations after the final stage of the treatment, mg/l	Calculated concentrations in the control point after dilution in the river, mg/l
NH_4^+	0.39	0.29	1.0	0.29086
Surfactants	0.1	0.031	0.1	0.03100
Suspended particles	12.55	12.3	10.0	12.3000
Phosphates	0.17	0.71	0.17	0.71000
COD	15.0	14.06	60.0	14.1162

water in a river (Kasprzyk-Hordern et al, 2009, Pant D, Adholeya A, 2007). As a result, concentrations of the controlled pollutants in the control point should be lower than the corresponding threshold values. Simulation of the dilution process and calculation of the concentrations in the control point have been performed using a special certified software "Maximum Permissible Discharge", which takes into account hydrology parameters of the river, rate of the wastewater discharge and concentrations of the pollutants at the discharge point. Additional peculiarities of the simulation related to a low-water object (Choban A, Winkler I, 2008, Choban A, Winkler I, 2011) have also been taken into consideration.

Results of the simulation are shown in Table 3. One can see that discharge of the treated wastewater does not result in any significant worsening of the river water quality. Changes in the concentrations of surfactants, suspended particles and phosphates remain beyond accuracy of the experimental determination while the latter value exceeds the threshold value even upriver from the wastewaters outlet. Discharge of the wastewaters causes raise in the concentration of ammonium-nitrogen and COD only for 0.3 % and 0.4 % simultaneously. Therefore, wastewater treatment depth using the recommended technology can be considered as appropriate. Discharge of the factory's wastewater into the river of Seret does not provoke excessive worsening of its quality.

Conclusion

An effective technology for treatment of the feather-processing factory's wastewater should be designed to decontamination of various types of the pollutants present in the water: finely dispersed mechanical pollutants, colloid, molecular and ionic inorganic and organic chemical agents. A consecutive three-stage technology including physicochemical coagulation/flotation, primary and secondary biotreatment with additional aeration and final sand-filtration ensures necessary depth of the cleaning. Even though concentrations of some important pollutants remain exceeding after the full treatment, discharge of the treated wastewater into Seret does not result in over-normal contamination because of natural dilution with river water. Other similar factories can follow this treatment technology for construction or renovation of their wastewater cleaning equipment.

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