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A CASE STUDY OF THE JUICE-MAKING FACTORY WASTEWATER TREATMENT AND POSSIBLE WAYS OF ITS OPTIMIZATION

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Abstract: *A general analysis of the typical juice making factory wastewater composition and its treatment technology is carried out. Since the technology used at the moment does not ensure effective decontamination and complete renovation of the wastewater treatment equipment is not feasible, some simple actions are proposed to improve the treatment quality. Possible efficiency of these actions is also analyzed and discussed.*

Keywords: *juice making; wastewater treatment; active sludge; biogenic components*

1. Introduction

Availability and quality of water resources are known to be the key factors of sustainable development of any country and normal health conditions of its population (World Health Organisation, 2010). Many water bodies in Ukraine have been degrading because the natural self-cleaning processes cannot cope with the amount of pollution they receive. As a result, the quality of water in many reservoirs that were previously used for drinking water supply has now dropped to the third class now (Dmitrieva et al, 2003). This process is caused mainly by massive discharge of untreated or poorly treated wastewater and every effort should be made to minimize this wrong practice.
Various food processing facilities are quite widely distributed in Ukraine and their wastewater treatment equipment is often very old and worn, which results in malfunctioning of the water cleaning technologies. Besides, food factories are often equipped with the wastewater treatment lines that were projected for the public (municipal) wastewater that does not always ensure the required cleaning of the industrial effluents.
Juice making factories can be referred to as an example of such improper realization of the food processing wastewater treatment. The main problem is caused by the strong acid reaction of the wastewater and rather low content of the biogenic elements (mainly N and P). Under these conditions, "normal" biotreatment of the wastewater is too slow and inefficient.
As reported (El-Kamah et al, 2010), the highest efficiency of the orange juice manufacturing wastewater decontamination can be achieved only in a combined technology with initial treatment in a two-stage up-flow anaerobic sponge reactor followed by the activated sludge reactor with approximately similar treatment periods in the both reactors. Traditional wastewater treatment technology includes only the latter of the above mentioned operations. Therefore, it is obvious that even thorough planning and realization of such technology cannot ensure the required level of the juice manufacturing wastewater decontam-

ination. On the other hand, there are references (Shepherd et al, 2001, Mosse et al, 2011) to quite successful functioning of the simpler wastewater decontamination systems. Shepherd et al (2001) reported a 98 % decrease in the chemical oxygen demand and 97 % in the total suspended solids content for the high-strength acidic winery wastewater treatment at a simple wetland landfill processing system combined with the sand prefilter. Extended reviews related to various winery and distillery wastewater treatment problems and technologies (mainly, decolourization) using various biological methods have been published by Pant, Adholeya (2007) and Mosse et al (2011).

Juice factories production has good market and constantly growing demand, causing rise in the production capacities and the amount of wastewater formed and discharged by this branch. Therefore, insufficient wastewater treatment seems quite a topical problem for any region of Ukraine with active fruit and vegetable processing. It should also be emphasized that more popular orange and some other tropical fruit juices technologies are analyzed in the majority of investigations related to this issue while many juice making facilities in Ukraine work with apple juice and their wastewaters are much more acidic and poorer with organic components. Therefore, it seems topical to investigate possible advances in treatment of this type of wastewater.

Some related and close problems of the wastewater treatment and its environmental effects have been discussed by Choban and Winkler (2008, 2011, 2012), Choban et al (2012) In this paper we analyze general problems of the juice making wastewater treatment. Some solutions for the wastewater quality improvement are also proposed and discussed.

2. Materials and Methods

General description of the actual wastewater collection and treatment technologies

This investigation deals with an analysis of the wastewater treatment technology, problems, environmental effects and possible ways of optimization on example of "BMB" juice making factory located in vil. Kobolchin, region of Chernivtsi, Ukraine.

This is a typical juice manufacturer and many similar factories are still working all over Ukraine. The factory is equipped with separated sewage systems for industrial and public wastewaters collection and transportation. A composition of the public effluent is typical for the moderately polluted wastewater (BOD_5 = 180 – 200 mg/l and pH = 6,5 – 8,5) while the industrial effluent is more concentrated and acidic (pH = 4,4 – 5,2; BOD_5 = 3500 – 4000 mg/l).

The total projected discharge is 168,57 m^3/day with only 31,11 m^3/day of the public wastewater. Therefore, industrial wastewater is a key factor that determines the quality and the quantity of the factory's discharge. Untreated industrial wastewater quality parameters are shown in Table 1 (column 3).

The general flowchart of the wastewater treatment technology is shown in Fig. 1. According to this technology, all collected wastewater is self-flowing to the treatment station. Then it is pumped to the receiver tank and then to the multisectioned settler-flotator.

Apple peels and seeds are filtered out in the first section at the arch sieve and then removed periodically. Then the wastewater flows to the next section for the acidity neutralization and adding some phosphorus and nitrogen compounds.

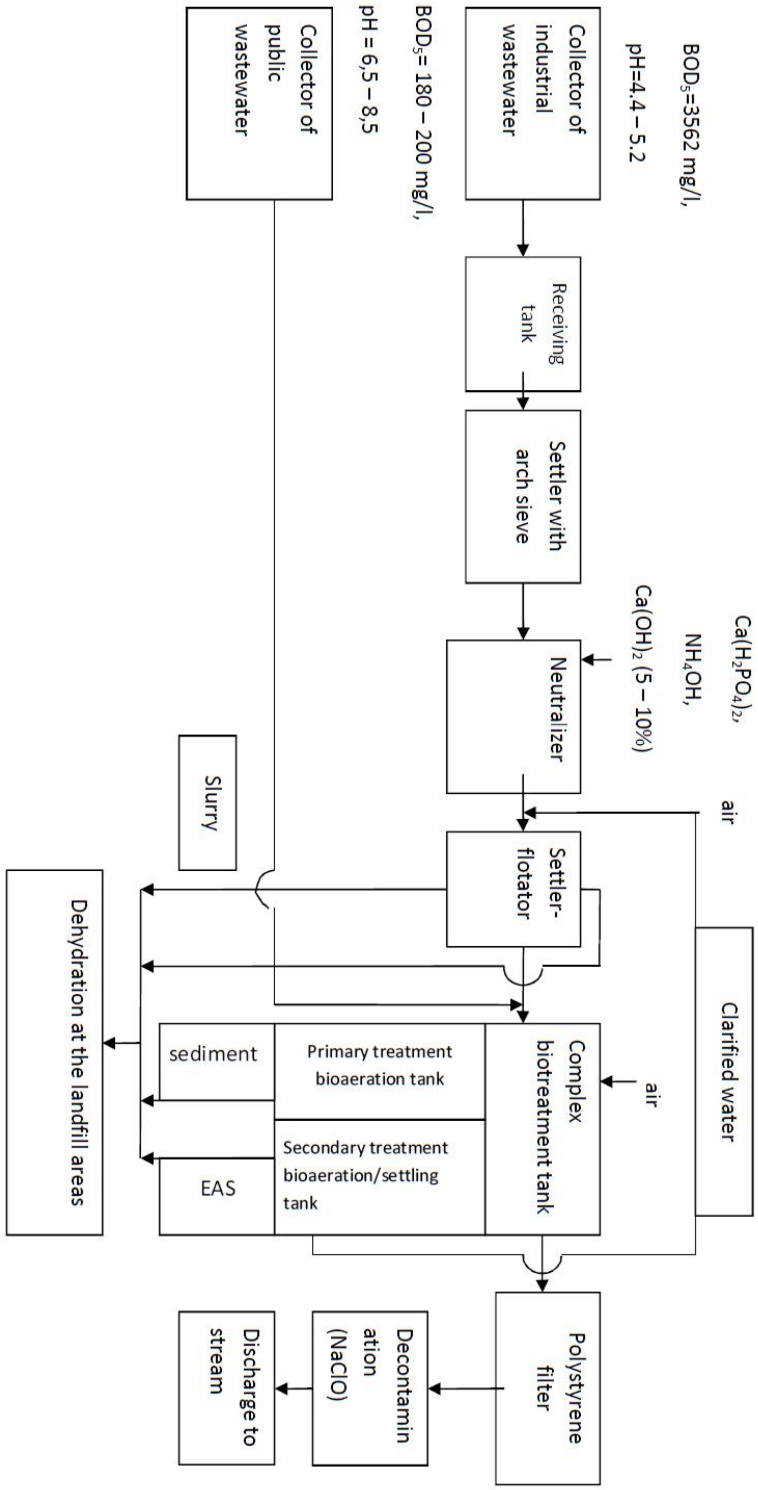

Figure 1. A technological flowchart of the current wastewaters treatment technology

The maximum calculated daily load of the nitrogen compounds is 32 kg and phosphorus compounds is 6,4 kg. Ammonia water (25 % of NH_3 or 20,6 % of N) is mainly used as a source of nitrogen and the partial alkalization agent. The calculated amount of this reagent is 156,3 kg/day.

Superphosphate (20 % of P_2O_5 or 8,7 % of P) is used as a source of phosphorus and the calculated daily consumption of this reagent is 73,6 kg. All amounts of the required reagents are determined in fact by the periodical lab analysis of the wastewater compositions. Any overdose is unwanted since it causes raise in the content of P and N in the treated wastewater.

Caustic soda or lime water are used for the wastewater neutralization. Lab analysis of the wastewater is also involved in determining the amount of these reagents required to bring pH to the range 6,5 – 8,5.

The combined settler-flotator (diameter 4,0 m) ensures removal of the coarse dispersed pollution by settling and then the remained suspended particles are removed by the pressure floatation with working liquid recycling. The required technological regime of the pressure floatation is maintained by saturation of the working fluid with air under pressure 0,4 MPa and its constant pumping to the floatation chamber.

The working fluid is formed initially from the primary treated wastewater after the settler-flotator and then from the clarified wastewater taken from the upper part of the secondary settler at the second stage of bioaeration. Saturation of the working fluid with air is realized in the pressure tank.

Biotreatment of the wastewater is realized by the two-stage technology. Most of the biopollution decomposes in the primary bioaeration tank while fine biocleaning and separation of the sludge mixture take place in the secondary bioaeration unit. A vertical baffle separates the latter unit into the central settling area and the peripheral area of aeration. The activated sludge does not receive high working load in this unit that ensures stabilization of the excessive sludge.

Both primary and secondary bioaeration tanks are equipped with highly effective stream aerators, and the atmosphere air is being actively captured by the working liquid stream, which results in its good saturation. The near-bottom activated sludge mixture is pumped out from the bioaeration unit and used as the working liquid for biocleaning.

An additional foamed polystyrene PSV filter equipped with the grains ranged from 8 to 20 mm is used for the wastewater fine cleaning. Finally, the solution of sodium hypochlorite is used for the bacterial decontamination of the wastewater. This reagent is added directly to the decontamination tank and its daily consumption is about 3,5 l/day (pure chlorine content is 170 g/l).

The stabilized excessive activated sludge is collected from the secondary bioaeration tank and then returned to the receiving chamber of wastewater treatment station. This solution is effective for biocoagulation of the mechanical pollution and its better settling. Then excessive sludge is filtered out in the settler-flotator together with the rest of the coarse dispersed particles. This equipment produces about 4,2 m^3/day of the sediments and 0,2 m^3/day of the floatation sludge. These components are being removed from the settler-flotator and sent for dehydration to the sludge storage area.

The treated wastewater is discharged to a small pool connected to the nameless stream.

The projected parameters of the treated wastewater quality are as follows: sediments – under 6,0 mg/l; BOD_5 – 6,0 mg/l; ammonia form of nitrogen – 0,5 mg/l; nitrites – 0,08 mg/l; nitrates – 40 mg/l; solid

residue – 1000 mg/l; sulfates – 100 mg/l; phosphates – 0,17 mg/l and chlorides – 300 mg/l (see Table 1, column 4).
However, our results of the wastewater quality control prove that the actual quality parameters are much worse than the planned values (see Table 1, column 5). Data in Table 1 show that the wastewater treatment equipment is far from its full efficiency and this technology needs in serious improvement and modification.

Table 1

Some parameters of wastewater quality

№	Pollution agent	Concentration, mg/l			
		Before treatment	After treatment		
			Projected values	Actual values of the treated wastewater	Expected values after implementation of our suggestions
1	pH	4.4 – 5.2	6.5 – 8.5	5.8	6.5 – 8.5
2	Sediments	853.0	6.0	54.3	15.0
3	BOD_5	3562	6.0	98,6	15.0
4	COD	8480.0	30.0	306.0	80.0
5	Nitrogen (ammonia form)	3.2	0.5	1.8	0.5
6	Nitrites	0.007	0.08	0	0.08
7	Nitrates	5.48	40.0	3.48	40.0
8	Solid residue	3226.0	1000.0	846.0	<1000
9	Sulphates	180.0	100.0	168.3	<500
10	Phosphates	0.625	0.17	5.8	0.5 – 1.0
11	Chlorides	629.0	300.0	172.0	<350

3. Results and Discussion

In our opinion, the realization of the current wastewater treatment technology at this juice making factory is poor because it was initially planned and designed for meat processing factories wastewater containing much more easily oxidizable components, biogenic elements (aminoacids, proteins, etc.) and with substantially milder pH (Choban, Winkler, 2008, Zapolsky et al, 2000). Another wastewater treatment technology providing discharge of the effluents with some amount of the added chlorella to the landfill areas seems more effective because this alga is capable to ensure biodegradation of the hardly oxidizable organics even in the acid solutions. The efficiency of this technology for the high-strength acid wastewater from wine producing factories has been reported by Shepherd et al (2001).
On the other hand, complete renovation of the existing wastewater treatment equipment and technology would require very serious investments and does not seem feasible. Since similar situation is typical for many other juice making factories in Ukraine and some other countries, it is important to pay attention to possible ways of improvement of the wastewater treatment using the existing equipment and technology.

Therefore, the following actions can be suggested to ensure the wastewater treatment improvement without major equipment renovation:

1. An equalizing tank should be added and used in the wastewater treatment;
2. Neutralization agents dosage should be automatically monitored and controlled;
3. The active sludge concentration should also be controlled automatically.

It is proposed to rise the activated sludge concentration at the biocleaning stage up to 4-6 g/l instead of the actual value 2,4 g/l. This suggestion is supported by the fact of better decontamination from the organic pollution performed by more concentrated sludge. BOD and COD values would decrease as a result of this operation as well as the ammonia nitrogen concentration (in case of active propagation of nitromonads). However, some additional amounts of the biogenic elements should be provided by adding superphosphate and the ammonia water to ensure additional activated sludge propagation.

On the other hand, excessive alkalization of the effluents disturbs normal development of the sludge (Zapolsky et al, 2000) and should be avoided. Acid reaction of the wastewater causes swelling of the sludge, which slips out from the secondary settlers and results in additional secondary mechanical pollution of the treated wastewater. So, the wastewater pH should be kept within the range 6,5-8,5 where the sludge is still active and can be effectively deposited under such values.

Badly controlled mechanical dosage of the reagents often brings pH outside of this range with either passivation or swelling of the sludge. An accurate automatic reagents dosage and/or installation of the equalizing tank can mitigate this problem and normalize conditions of the active sludge propagation.

4. Conclusion

The general assessment of the results of the above mentioned steps realization is shown in Table 1 (column 6). It can be seen that the most dangerous parameters would drop after implementation of our suggestions while the increase of some other parameters (solid residues, sulphates content) would not bring them above of the maximum permissible levels. It should also be emphasized that the ammonia nitrogen content decreases too and this causes better protection of the natural water bodies from eutheriphication. Mathematical simulation of changes in the receiving water body proved that it would remain conforming to the fish-farming class even receiving discharged wastewater treated in the proposed way.

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