

WASTEWATER TREATMENT IN FOOD INDUSTRY

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Abstract: The food industry main role is to provide sufficient quantities of food for the population. Intensive production contributes to greater environmental pollution as well as the nutritional value of food products is lower, so it is necessary to introduce a larger amount of food into the body to access the needs of the body. Environmental protection is very important for the food industry and the largest amount of waste materials are created by dairies, confectionery manufacturers, beverage manufacturers and meat processors. The aim of the paper is to introduce the wastewater treatment process in the meat industry and the applied protection measures related to environmental protection in the production of meat products.

Key words: wastewater, wastewater treatment in food industry, meat products

1. INTRODUCTION

The increase in population and rapid social growth have led to the intensification of food production. Land use is more intensive, and therefore the application of modern agrotechnical measures, the use of artificial fertilizers and other plant protection products, due to the increase in yield, but at the same time leads to additional pollution of watercourses and groundwater. [1]

Meat production, from livestock farming to meat processing and obtaining meat products, is a large consumer of water, but also a large producer of highly organically loaded water, i.e. a major polluter of water surfaces.

According to an epidemiological and epizootiological aspect, by-products and waste of animal origin in meat production industry and processing must be treated as potential sources of infectious diseases of humans and animals. Dead animals and by-products of the slaughterhouse industry undergo a decomposition process, which leads to smelly and toxic gases that pollute the air, water and soil. Waste materials from the meat industry end up in the sewers, and then in waterways, where they serve as food for many pathogenic microorganisms. The process of decomposition of organic waste also affects the increase in biological oxygen consumption. [2]

2. WASTEWATER MANAGEMENT

Meat industry wastewater typically contains fat, blood and animal hair, as well as increased levels of salt, which is often used in meat processing, resulting in high HPK and BPK₅ values. The normal level of wastewater contamination is above the permissible limit and treatment is necessary. Since meat industry wastewater has an extremely high organic pollution, several processes must be implemented to

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ensure satisfactory effluent quality. Wastewater treatment is based on biological treatment combined with mechanical, chemical and physico-chemical processes. [3,4]

2.1 Coarse and fine mechanical wastewater treatment with equalization – sieve in the channel

Mechanical (or physical) treatment removes coarse impurities, inert materials and some biodegradable components from wastewater. Mechanical treatment is carried out using grates, sieves, sand traps, grease traps, primary (preliminary) sedimentation tanks and basins for equalizing the flow and composition of wastewater (when it changes significantly during the day).

Considering that part of the total pollution of wastewater from the meat industry is represented by biodegradable, coarse suspended matter, which can cause blockage of important parts of wastewater treatment plants and can be easily degraded.

2.2 Wastewater Collection and Treatment Process - Pump Pit

The wastewater collection and treatment process begins with the discharge of wastewater through an internal sewer and a coarse grate, Figure 1, into a pump pit, Figure 2. The water retention time in the pump pit is short to reduce the possibility of solids settling.



Figure 1 Grate

(source: author archives)



Figure 2 Pump pit

(source: author archives)



Figure 3 Rotary sieve

(source: author archives)



Figure 4 Flocculant

(source: author archives)

The influent is pumped from the pump pit into a rotary sieve, Figure 3, which removes suspended and floating material with dimensions of about 1 mm (opening aperture 0.25 - 1.5 mm).

The rotary sieve, designed in the form of a drum, is partially immersed in water and movable so that the accumulated material is removed from the part of the sieve that is outside the water, by a jet of water from the inside of the drum. In this way the clean surface of the sieve is restored. The sieve is protected from coarse material by a previously installed grate. A knife is mounted on the sieve that removes solids from the drum. The separated material is received in a container.

The equalization of the flow, wastewater concentration, pH value and temperature is then carried out in the equalization basin. A mixer is installed in the basin, which is used to homogenize the contents of the basin.

The retention time of wastewater in the equalization basin must be sufficient to equalize oscillations.

3. SEPARATIONS OF FATS FROM WASTEWATER

Flotation is one of the physico-chemical methods of wastewater treatment, which is used to remove suspended and floating particles from wastewater (oils, fats, emulsions, etc.) whose density is lower than of water density. Flotation is usually used in the wastewater treatment originating from: the food industry (meat industry, dairy industry, slaughterhouses, fruit and vegetable processing, oil processing, ...); the paper industry; the metal industry; refineries, etc.

Wastewater generated by meat processing from the equalization basin is further transported to the DAF device (DAF, eng. Dissolved Air Flotation) for the removal of fats and oils. Flotation is a mechanical separation process based on the creation of a supersaturated solution of air in wastewater, i.e. microbubbles come into contact with dispersed fats and suspended solids, bind to them and allowing them to rise to the surface and float. In the phase preceding flotation, coagulation and flocculation processes, Figure 4., a coagulant is added to the wastewater to neutralize the electrostatic charge of colloidal particles and enable their agglomeration into flocs, and a flocculant (polyelectrolyte), which binds the neutralized particles into even larger flocs.

During the coagulation process, intensive mixing is carried out for a short time. Since the salt used as a coagulant hydrolyzes in an aqueous solution, this hydrolysis releases acid, which causes the solution to react acidically. Therefore, bases (for example, sodium hydroxide) must be dosed simultaneously with the addition of the coagulant, thanks to which the pH is maintained within the limits of around neutral values and the precipitation of stable flocs is possible. In order to form sufficiently large flocs, which can be separated by flotation, the flocculation process is allowed to last longer and the mixing intensity is reduced, which prevents the fragmentation of already formed flocs.

During operation, a mixture of air and water is introduced into the flotation tank under pressure (in a pressurized pipeline, air dissolves in water), which causes the expansion of the dissolved air in the form of microbubbles. The generated bubbles merge with particles from the wastewater and, using the force of the pressure, float together to the surface of the water, thus generating floating sludge. The floating sludge is constantly removed into the sludge compartment and drained into a suitable container, while the sludge from the bottom of the flotation tank is removed.

Saturation is the most important aspect of a DAF unit. Saturation is the result of the dissolution of air in water by increasing the pressure. The pressure in the saturation tube can be adjusted. The standard pressure used to dissolve air in the water jet for cleaning is between 5 and 6 bar. This air-saturated water is then pumped to the bottom of the DAF unit where it is discharged to atmospheric pressure, causing the air dissolved in the water to form bubbles. The tubular saturator is designed to allow air bubbles of several tens of micrometers in size, which gives exceptional efficiency. These microbubbles of air “pick up” particles of grease and suspended solids on their way to the top, and by the force of pressure they carry them to the surface.

Solids, which are present in the wastewater, and whose densities are higher than the density of water (sand and other heavy particles) settle to the bottom. A sediment drill is used to remove them. The solids settle, and the drill transports these solids to a location at the bottom of the DAF. An automatic valve opens to release the settled solids, which are then discharged. The sediment drill operates with interruptions between pulses.

The speed and depth of immersion of the flotation sludge removal device determines the moisture content of the sludge. Increasing the speed of this device will increase the percentage of water in the sludge. The sludge must be wet enough (8 to 10% dry solids content) to be pumped without damaging the pump. By immersing the device deeper in the water, a significant amount of water is removed along with the sludge, and the sludge will be wetter.

4. BIOLOGICAL WASTEWATER TREATMENT

For biological wastewater treatment, a sequential batch reactor (SBR) is used, shown in Figure 5, which is based on the activated sludge process and aerobic sludge stabilization. Continuous operation of the system is planned, which is divided into two functional parts: the wastewater receiving part and the SBR reactor. Anaerobic biological decomposition of waste materials takes place in the SBR reactor using activated sludge. One water purification cycle takes place through four phases and excess sludge is transferred to the sludge tank, after which it is dehydrated and conveniently stored.

The first part is the filling phase and the second is the reaction, sedimentation and discharge phases, i.e. at any time the plant will operate continuously and be able to receive the maximum flow of wastewater. There are four basic cycles of wastewater treatment in the SBR system:

- *charging sequence* – in conditions without aeration, wastewater is introduced into the sludge layer, with the water level varying from 25 to 100% of the tank capacity. The charging process is controlled by the charging time and the water level in the tank.

- *reaction sequence* – this phase includes mixing and aeration in the tank using surface aerators, in order to complete the reaction started in the charging phase. During the aeration phase, organic matter is oxidized, nitrogen undergoes nitrification processes, and phosphorus is removed from the water via the sludge. During the time when there is no oxygen supply to the water, the denitrification process will take place in the anoxic zone. The purpose of denitrification is to remove nitrogen compounds in the form of nitrogen gas and release oxygen from nitrates;

- *sedimentation sequence* – the sedimentation period occurs when the mixing and aeration processes in the reactor stop, when the reactor content is completely still. The purpose of sedimentation is to separate the formed activated sludge and to separate the purified water. Due to the great depth of the basin, the sedimentation process is expected to be very efficient;

- *discharge sequence* – after the formation of a certain depth of supernatant, the discharge phase occurs after the sedimentation process. The purified water is discharged from the reactor using a decanter into the effluent tank, while the discharge of sludge from the basin is prevented thanks to the decanter design itself.

Under aerobic conditions, microorganisms decompose organic matter from wastewater into carbon dioxide, water and ammonia, increasing their biomass. Ammonia, with appropriate types of bacteria, in the presence of oxygen, is first oxidized to nitrite and then to nitrate. Phosphorus is removed from wastewater in the presence of oxygen by bacteria that convert soluble phosphates into insoluble polyphosphates.

The necessary oxygen for this process is provided by an aeration system. Depending on the type of aeration system, submersible mixers are used or the aeration system is used to maintain the sludge in suspension.

In order to prevent the formation of filamentous bacteria in the aeration tank, the wastewater is mixed with the return activated sludge. Mixing is important and the entire tank must be well mixed to homogenize the activated sludge. In normal operation, the mixers should operate continuously (24 hours per day, 7 days per week). The biological treatment system works best when flocculating bacteria are used. Filamentous bacteria can have a negative impact on the process. Filamentous bacteria have a reduced settling capacity and are less compact. This primarily creates a problem during the separation of water from sludge. Therefore, floc-forming bacteria are preferred over filamentous bacteria. Filamentous bacteria grow better in conditions where low oxygen levels and low food concentrations are present. (They are more efficient because they have a larger total surface area.) By providing a high ratio of food to biomass, the floc-forming bacteria grow stronger and increase in number. The ratio of food to biomass is controlled by the flow of the return activated sludge. By reducing the flow of the return activated sludge, the ratio of food to biomass increases.

In the denitrification process, in anoxic conditions, instead of oxygen, bacteria use nitrates, which are formed during the nitrification process, to oxidize organic matter, which they incorporate into their biomass. Nitrates are converted into gaseous nitrogen, carbon dioxide and water. Anoxic conditions in the denitrification tank are achieved by mixing wastewater and recycled activated sludge without aeration. Mixing is important during the denitrification process. The entire tank must be well mixed to keep the activated sludge in suspension and to prevent its sedimentation, Figure 5.



Figure 5 Denitrification tank
(source: author archives)



Figure 6 Sludge tank
(source: author archives)

Sludge settling ability is extremely important in systems where sludge settling is used to separate sludge from treated wastewater. Good settling is facilitated by "strong, healthy" flocs, which settle quickly to the bottom, leaving a clear layer of water on top. In contrast, significant development of filamentous bacteria makes sludge settling difficult, causing it to float and form foam.

The SBR system is equipped with sludge recirculation pumps and submersible sludge pumps that will transfer excess sludge to the thickening process, to the centrifuge before the dehydration process. The treated water from the SBR system is discharged into a natural water recipient until the construction of a central wastewater treatment plant, when the effluent will be discharged to this plant via the public sewer.

The sludge tank, Figure 6, is used to collect sludge from various stages of wastewater treatment and transfer it to the sludge dewatering unit. Its primary purpose includes collecting and homogenizing different types of sludge and transporting them to the sludge dewatering unit.

The possible disposal of the sludge produced in the DAF unit, with the least negative consequences for the environment, is after prior stabilization of the sludge using an aerobic digestion process. In the sludge stabilization process, glycerol and fatty acids are formed from the esters of the flotation sludge during hydrolysis, and in the aerobic digester, with the help of microorganisms and oxygen, these products are oxidized into highly biologically stable, odorless products.

If the sludge dewatering unit is installed after the sludge tank, a pump is installed to transport the sludge to the sludge dewatering unit.

The sludge retention time in the tank is important, because if the sludge is kept in the tank for too long, acidification and the formation of an unpleasant odor can occur. Generally speaking, the sludge tank is emptied to the sludge dewatering unit once a day.

A mixer, built into the sludge tank, is used to homogenize the tank contents.

A decanter centrifuge is used to condition the sludge and reduce the moisture content in the sludge. In order to improve the characteristics of the sludge cake, i.e. to increase the concentration of particles in the sludge cake, a polyelectrolyte solution is dosed just before the sludge enters the decanter. The resulting filter cake is transferred to a container and then deposited.

5. CONCLUSIONS

The generation of wastewater from the meat industry represents a significant environmental challenge that requires careful management and treatment. Due to its complex chemical and biological structure, the proper treatment of wastewater is crucial for the protection of the environment and human health. When wastewater is purified, many producers in the meat industry decide to either discharge it into a recipient, i.e. rivers, or it can be used for irrigation or other purposes.

It is important to note that purified wastewater, although significantly less polluting, may still contain certain substances that can affect the environment, so it is necessary to conduct regular water quality tests. In addition to direct processing procedures, the meat industry can also implement various strategies to reduce the amount of wastewater generated. This includes optimization of production processes, use of closed water cycle systems, recycling of waste water within the plant itself. Such approaches not only reduce the environmental footprint of the industry, but can also reduce costs associated with wastewater treatment and disposal.

Wastewater management in the meat industry is a challenge that requires a multidisciplinary approach. In addition to technical solutions, it is also important to educate workers in the industry about the importance of proper waste water management and its impact on the environment. Given the concern about growing environmental problems, the meat industry must find sustainable solutions that will reduce the negative impact on the environment.

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