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WASTEWATER CONTROL SYSTEM AS AN ASPECT OF ENVIRONMENTAL ASSESSMENT OF INDUSTRIAL ENTERPRISE'S ACTIVITY

In order to reduce the influence of wastewater from enterprises on the environment extreme relevance is gained by improvement of the monitoring system at each stage of technological process. A new tool is calculation of the polluting substances concentration is suggested to be entered into the monitoring system on the basis of determination of material balance of technological process of production that will allow prediction of qualitative and quantitative composition of sewage for the selected period. The system can be used in any enterprise, but the example with all calculations is given for the Mykolaiv Branch of "SUN InBev Ukraine" which became the object of research. The scope of the study covered the process of wastewater formation of the enterprise. Realization of tasks demanded the use of general scientific methods: analysis, synthesis, systematization and generalization in the course of studying of the corresponding literature on the research subject; modelling, formalization, comparison – at drawing up the calculation scheme of concentration of the polluting substances in sewage; supervision - during studying the technological scheme of production; and also methods of mathematical data processing in MS Excel.

Keywords: wastewater, pollutants, material balance, environmental management

1. Introduction

Sewage from industrial enterprise is the main source of pollution of superficial water objects. The issue of environmental security enterprises of food industry, namely the aspects of qualitative composition of effluents, is presented

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in publications (2–5). Control of sewage from plants now has only the statistical character. Therefore extreme relevance is gained by improvement of the monitoring system behind sewage at each stage of the technological process taking into the rules of acceptance of wastewater and surface water objects according standards (6; 7; 8−11). The system consists of drawing up a material balance of the technological process, definition of the main polluting substances on the basis of calculation of masses and concentration of the substances in sewage made for a certain period. A similar system allows seeing a full picture of impact of the enterprise on the environment, in particular on the water resources, to know, what impact each process has on the enterprise in the general sewage pollution. The system helps to determine the concentration of those substances in wastewater which is not defined with the use of laboratory measures. Though, complete to replacement of the laboratory control over sewage is not the purpose of the offered system, it can add its results, because single tests on wastewater are not always indicative.

The objective of the research is the modernization of the wastewater control system on the basis of calculation of substances' mass balance. In order to meet the objective there is a need to solve the following problems:

- the analysis of the technological process of the enterprise, drawing up scheme of sewage formation;
- the calculation of concentration of the polluting substances in sewage of the plant for a certain period;
- the development of recommendations on optimization of the wastewater control system.

The offered system can be used at any industry enterprise, but the example with all calculations is provided for the Mykolaiv Branch of "SUN InBev Ukraine" which became the object of the research. The formation process of wastewater of the enterprise has been selected as the scope of research.

General scientific methods are applied in order to execute the tasks such as analysis, synthesis, systematization and generalization; modelling, formalization, comparison drawing up the scheme of calculation of the polluting substances concentration in sewage; supervision during studying the technological scheme of production and also methods of mathematical data processing in MS Excel.

2. Methods and experimental procedures

The modern wastewater control system in Ukraine consists in periodic sampling, carrying out the laboratory analysis of their structure and informing the enterprise on the conducted research (Fig. 1). However, the prospect of achieving sustainable development is possible when not only a simple measurement of sewage composition is taken, and when their structure is controlled at each production phase. Such system allows the presentation of a positive impact of the plant on the environment, to estimate the contribution of

each division to the general influence, to control the sewage formation process and to operate production in order to reduce the impact on the environment. There is a possibility of forecasting the qualitative and quantitative composition of sewage for any period in all divisions of the enterprise, which is an essential addition to the laboratory methods of analysis, which are not always indicative, demand time, not all elements of a substance can be defined.

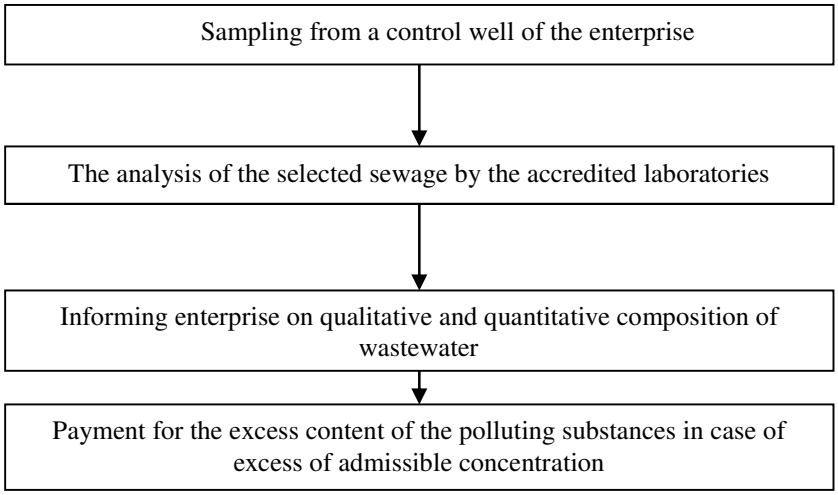

Fig. 1. The present wastewater control system

For modernization of the wastewater control system there was a need of studying of the technological scheme of production. The analysis of the process (the production of beer as an example of enterprise "SUN InBev Ukraine") showed the main points of wastewater formation:

1) Reception of barley and malt (there is no use of chemicals and dumping of industrial sewage).
2) Barley crushing (there is no use of chemicals and dumping of industrial sewage either).
3) Preparation of water for beer production: chemicals for reduction of water in the corresponding quality are used.
4) Preparation of beer wort consists of the following stages:
   - grout – extraction of malt's soluble substances and transformation under the influence of enzymes of insoluble substances;
   - filtration – separation of beer mash from a pellet. Mash and insoluble substances in water - a pellet is received [5];
   - mash boiling with hop. Mash comes to the machine where hopes are added and boiled. Mash is sterilized during cooking; enzymes are inactivated; bitter substances of hop are dissolved in mash, proteins coagulate [2];

- separation from hop and cooling [5]. The sewage containing organic pollution, particles of diatomaceous earth, a pellet and the dissolved components of detergents are respectively formed.

5) Mash is fermented. Special types of cultural yeast are used in brewing which ferment mash with formation of alcohol and carbon dioxide [3]. Fermentation takes place in two stages:
   - main fermentation. It is characterized by intensity of the process and fermentation of the most part of sugars (maltose, glucose, fructose and others);
   - young beer is cooled for the best sedimentation of yeast and transferred for the subsequent main fermentation.

   The waste, containing organic pollution, shares of yeast, pellets, beer and dissolved components of detergents are respectively formed.
6) Ready beer is filtered on the kizelgur filters. For beer which is poured in barrels, using separations. At this stage water and detergents are used, the sewage containing components of the used means and organic pollution is formed [3].
7) Preparation of a container and beer barrelling: water for washing a container with the use of the aggressive washing substances. The sewage is sated with various aggressive substances from the remains of labels gets to the sewage, flew down and so forth.
8) Department of quality control of beer: a number of chemicals which are necessary for determination of quality indicators of the ready-made product, mash, malt, water and so on are used. Insignificant pollution of very low concentration gets to sewage.
9) Department of logistics: low-quality beer merges in the sewerage that means high organic pollution.
10) Auxiliary production: water is also used for economic domestic needs.

The carried-out analysis allows determination of the main divisions polluting sewage such as department of brewing, including filtration, packing and logistics. Therefore it is necessary to study the means that are used in these divisions, and what polluting substances compose the sewage. The brewing department uses a number of chemicals and means. At the brewing stage: solution of nitric acid HNO_3; solution of phosphoric acid H_3PO_4; solution of sodium hydroxide NaOH; P3-stabicip OXI; P3-topactive 200; at the stage of fermentation and filtration of beer: solution of nitric acid HNO_3; solution of sodium hydroxide NaOH; P3-oxonia active 150; P3-topax 66; P3-oxonia; P3-trimeta DUO; Hlorantoin; P3-ansep CIP. The mentioned substances get to the sewage together with organic pollution: shares of the yeast; extract losses; beer losses; diatomaceous earth shares; share pellet.

The packaging department of uses the following materials: solution of phosphoric acid H_3PO_4; solution of nitric acid HNO_3; solution of sodium

hydroxide NaOH; P3-oxonia active; P3-topax686; P3-topax 56; P3-stabilon WT; P3-oxonia; P3-stabilon plus; P3-topactive 200; P3-topactive DES; DryExx; P3-polix XT; P3-lubodrive; P3-oxonia active 150; P3-ansep CIP.

The Logistics department conducts regular showers substandard products.

The chemical compositions of means which are used by enterprise were studied. For example, detergent P3-topax56 is characterized by the following composition: H_3PO_4 – 25÷30%; 2-(2-butoksyetoksy) ethanol – 2.5%; surfactant (alkylaminoxides) – 2.5%; P – 9.6 %, N – 0.18%, COD – 170 mg O_2/g. Similar results obtained for all means, but we choose to calculate the average amount of each substance content.

The technological scheme of production with the image of the main stages is made for modernization of wastewater control system. We will represent all necessary resources, chemicals and means which are used in the enterprise and which as a result can get to the composition of sewage in Fig. 2. Thus technological operation is "a black box" for us. We are interested in only those substances which are on the entrance and at the exit at the technological process.

At the exit, wastewater will be full of those substances that are used in the company at a particular time. Besides, from the brewing department the remains of beer, yeast, diatomaceous earth, a pellet and extract get to the sewage. Their structure may be different, however, for calculation we use their average data given to contents of nitrogen, phosphorus and COD.

Analyzing the composition of the means used at the enterprise, the structure of organic pollution, and the Rules of Admission of Sewage in the Municipal Sewerage of the City to control composition of sewage, we choose the following indicators:

- COD − this indicator is given for all used means, and also for organic pollution. It is an integrated and informative indicator of water pollution [4];
- phosphates are a part of some means;
- surfactants are part of some means;
- nitrogen content calculated by the nitrate form, as part of some assets is nitric acid. Nitrogen in the ammonium and nitrite form, regulated by the Rules, is not contained in the compounds, but it is a part of organic matter, and then can go into the ammonia, nitrite and nitrate form. Based on this we also take into account the total content of nitrogen.

As daily calculation is made generally to know the load of local treatment facilities, it is necessary to consider also the general content of phosphorus. Therefore this indicator will also enter the calculations.

The analysis of structure of the used substances shows that the numerous amounts of chemicals are their part. All these substances will be presented in the form of certain indicators: COD, phosphates, surfactants, nitrates, general nitrogen.

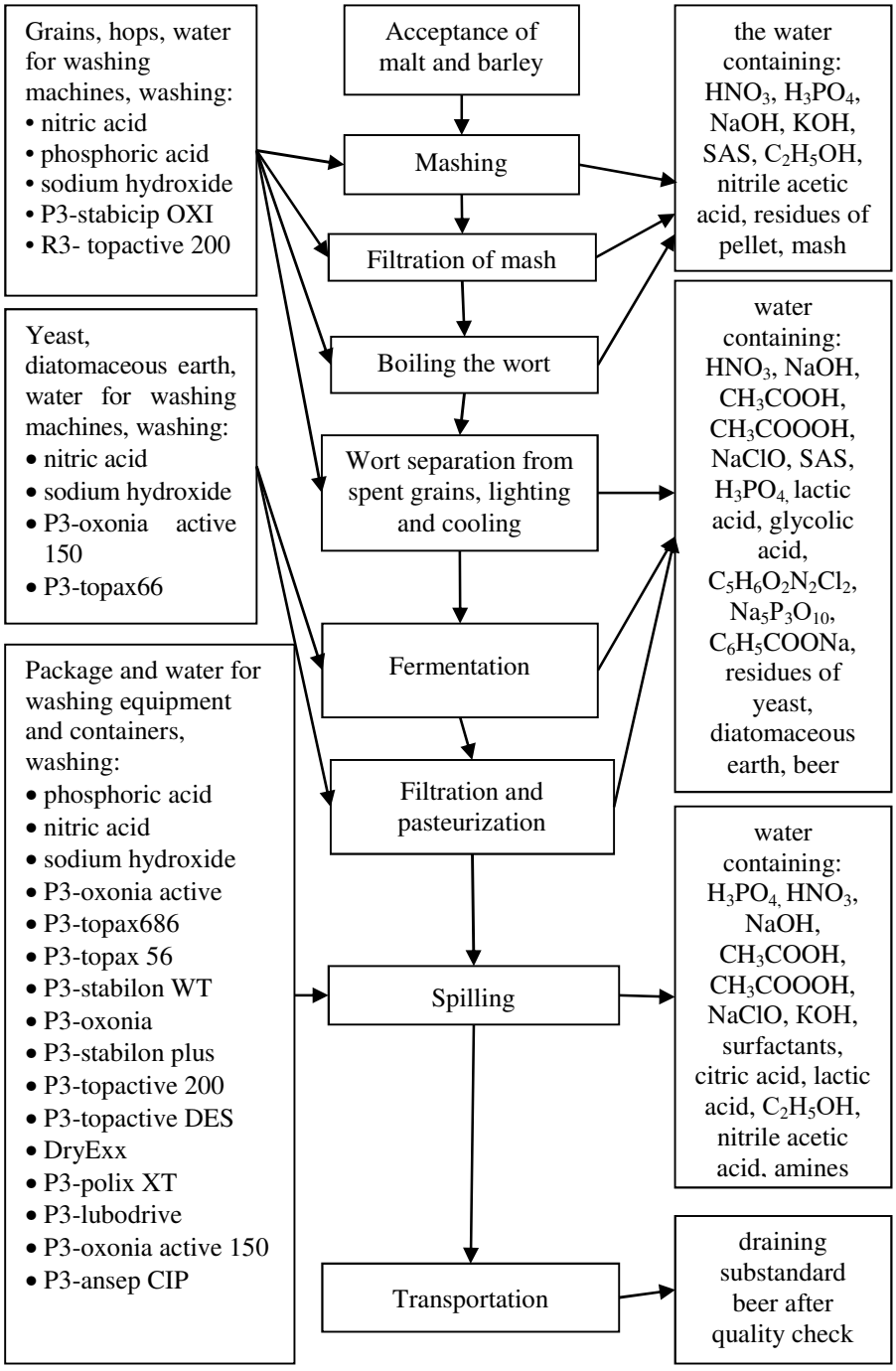

Fig. 2. Scheme of wastewater formation

The calculation procedure is presented by the list of actions. The example is given for one month:

1. To determine the mass of a pollutant using the formula (1):

$$m(pollutant) = w(pollutant\ in\ mean) \cdot m(men) = \frac{M(pollutant\ in\ substance)}{M(substance)} \cdot w(substnce\ in\ mean) \cdot m(mean), g \quad (1)$$

where: *M (pollutant in substance)* − the molar mass of the pollutant in the substance, g/mol,
M (substance) − the molar mass of the substance, g/mol,
w (substance in mean) − mass fraction of substance containing pollutants in means,
m (mean) − the mass of the used means, g.

The calculation was performed for each of the selected pollutants, determining the mass of phosphate, nitrate, total nitrogen, surfactants, COD and for each mean used in departments: brewing, packaging and logistics. For example, to find the mass of phosphates, we determine their weight in substance which contains phosphates. In the brewing department of phosphates contain only in P3-trimeta DUO in the form of phosphoric acid. For example we find the mass of phosphates using the formula 1 if we know the mass of means and a share of phosphoric acid:

$$m(PO_4^{3-} in\ P3 - trimeta\ DUO) = \frac{95\frac{kg}{kmol}}{98\frac{kg}{kmol}} \cdot 0.4 \cdot 525kg = 203.57\ kg$$

COD indicator for each means is given in mg O_2/g, and the mass of means is considered in kg. Therefore COD for various means is determined by a formula (2):

$$COD_{tot.mean} = COD_{mens} \cdot m_{mean} \cdot 1000, mg\ O_2 \quad (2)$$

For organic pollution we use the accepted data, considering the formula (3):

$$COD_{tot.substance} = COD_{substance} \cdot m_{substance} \cdot 1000, mg\ O_2 \quad (3)$$

To calculate the COD for the brewing department one should consider the following substances: P3-topax66, P3-trimeta DUO, P3-ansep CIP, and the remains of diatomaceous earth, yeast extract and beer pellet that enter the wastewater.

2. Determine the total mass of a particular pollutant in the department and across the entire enterprise according formula (4).

$$\Sigma m(pollutant) = \Sigma m(pollutant_{d.brewing.}) + \Sigma m(pollutant_{d.packaging.}) + \Sigma m(pollutant_{d.logistics.}) \quad (4)$$

where: $\Sigma m\ (pollutant_{d.brewing.})$, $\Sigma m(pollutant_{d.packaging.})$, $\Sigma m(pollutant_{d.logistics.})$ - the total weight of a particular pollutant for a specific branch, consisting of a mass of pollutant in each mean.

3. To determine the concentration of pollutants using the formula (5):

$$c(pollutant) = \frac{\Sigma m(pollutant) \cdot 1000}{V(wastewater}, g \cdot m^{-3} \quad (5)$$

where: $\Sigma m\ (pollutant)$ - the total mass of pollutants in all substances, kg,
$V\ (wastewater)$ - the amount of wastewater for a certain period, m^3.

Example of calculation of concentration of phosphates (volume of wastewater is 14,779 m^3):

$$c(PO_4^{3-}) = \frac{482.97kg \cdot 1000}{14779m^3} = 32.67\ \frac{g}{m^3}$$

4. To predict the level of pollution and to make the relevant decisions, for each substance we determine the planned volume of its usage, and also we can compare the planned norm of use with a real volume. Such tool allows fast identification of the main sources of pollution, those departments which exceed the norms of use and to taking measures for rapid response to reduction of impact on the environment. For this purpose in calculation we will define not only the actual volume of use of means, but also the planned one. For determination of the planned mass of use of a certain means we use a formula (6):

$$m_{planned} = norma \cdot V_{panned.bear} \quad (6)$$

here: *norma* – the rate of use of a specific product, $kg \cdot hl^{-1}$,
$V_{planned.besr}$ – the amount of beer that planned release, hl.

Here is an example of calculation for the brewing department of nitric acid, $V_{planned.bear} = 78930$ hl:

$$m_{planned}(HNO_3) = 0.07\frac{kg}{hl} \cdot 78930ch = 5525.1kg$$

To calculate the actual number of specific product per a production unit, use the formula (7):

$$costs = \frac{m_{actual}}{V_{actual.beer}} \tag{7}$$

where: m_{actual} – the actual mass of the used means, kg

$V_{actual.beer}$ – the volume of beer actually released, hl.

5. The result is the generalized data where the mass of the polluting substances on departments, their total mass and concentration are specified.

To show viability and effectiveness of a similar calculation we show the obtained data in the form of the schedule. Fig. 3 shows the calculated COD for the selected period indicating the volume of beer produced.

Such calculation is necessary to exercise control of compliance to admissible concentration not to be relied by single analyses which often happen inexact, for decision-making and modification of the technological processes, for adaptation of the technological process of production to new requirements, for the best representation of an overall picture of activity of the enterprise.

Thus, the proposed system of calculation of concentration of the pollutants is the additional effective instrument of the wastewater control system of the plant, allows identification of the processes that causes the most pollution. This system allows making decisions on reduction of influence on environment by change or improvement of production process, replacing some means so on (Fig. 4).

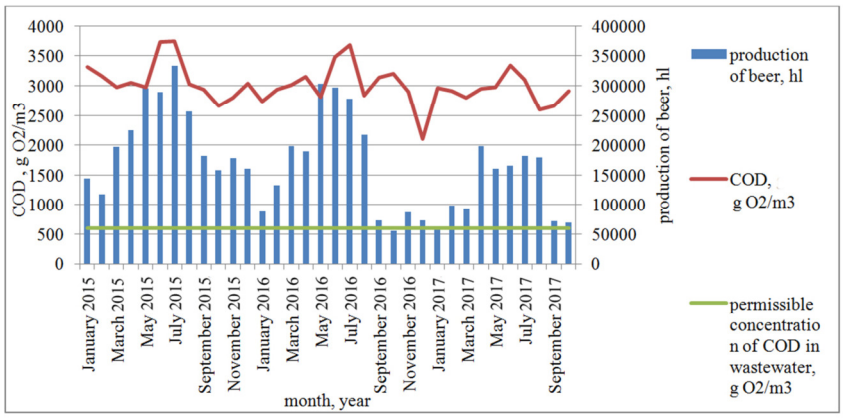

Fig. 3. The dynamics of the COD indicator changes calculated COD of wastewater

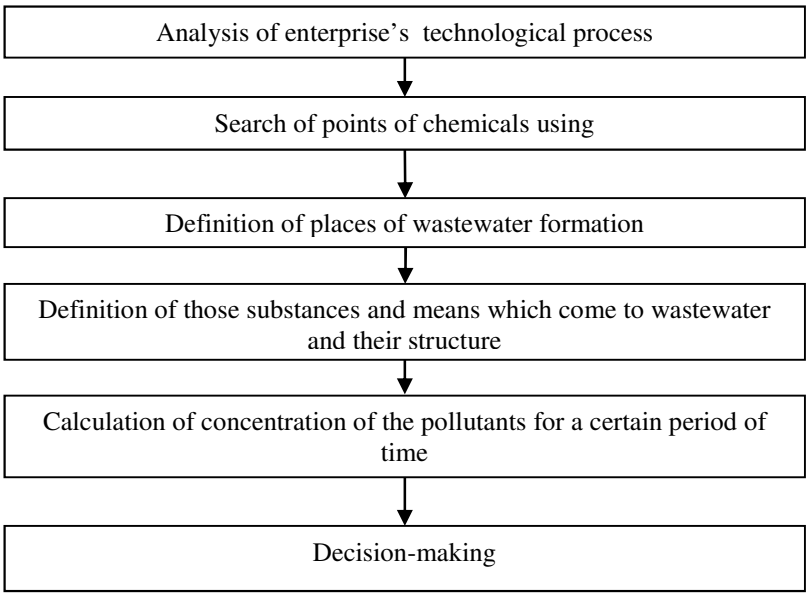

Fig. 4. The modernization wastewater control system

3. Conclusions

The proposed wastewater control system is one of the main aspects of environmental assessment of industrial enterprise's activity. The main problem of the plants of the brewing industry is the use of a great amount of water and the formation of the wastewater polluted by various substances. The pollutants consist of a pellet, diatomaceous earth, yeast, beer remains, etc., and also components of those means which are used in the plant in the certain period of time. The wastewater control system has the stating character: single tests at the exit from the enterprise one time a week are investigated, and then it is determined if the company complies with the standards, but this approach is not quite correct. Therefore, there is a need to carry out a continuous wastewater control by the introduction of the new tool on the basis of calculation of the pollutants concentration.

This system has a number of functions: illustrative, as it shows all production processes and gives a better picture of the overall impact on the environment; controlling, as calculation shows the stage on which of the process the most waste water is generated, which unit is the biggest polluter; the result is valid, not single concentration of pollutants; predicting: by data of the use norms of means and of the planned quantity of production, we can expect the qualitative and quantitative composition of wastewater at the exit from each department and from the enterprise in general; management, after all, on the basis of the analysis of the obtained data on processes which make the greatest

pollution, it is possible to make operational decisions on reduction of impact on environment; informative: provided data on the concentrations of substances, including those that are not controlled by laboratory methods.

The recommended system is not intended to replace the laboratory analysis. It is the additional effective wastewater control instrument. It may be adapted for any other production.

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