Scientific quarterly journal ISNN 2083-1587; e-ISNN 2449-5999

Agricultural Engineering

2015: 4(156):79-89

Homepage: http://ir.ptir.org

DOI: http://dx.medra.org/10.14654/ir.2015.156.154

MODERNIZATION OF THE WASTEWATER CONTROL SYSTEM IN THE FOOD INDUSTRY

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ARTICLEINFO

Article history:
Received: August 2015
Received in the revised form: September 2015
Accepted: October 2015

Keywords:
wastewater
pollutants
material balance
control
management
food industry

ABSTRACT

In order to reducethe 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 - calculation of the polluting substances concentration is suggested to be entered into the monitoring system on the basis of determination of material balance of the 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; modeling, 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.

Introduction

Today sewage from plants is the main source of pollution of surface water objects. The issues of environmental security of food industryenterprises, namely the aspects of qualitative composition of effluents, are presented in publications (Kolotyloet al. 2003; Kunze, 2001; Muravyov, 2004; Kovalevskaya, 1993). Now,control of sewage has only the statisticalproperty. Therefore, extreme relevance is gained by improvement of the monitoring system of sewage at each stage of thetechnological process taking into account applicable standards of the rules of acceptance of wastewater and surface water objects(1; 2; 7-10). The system consists in drawing upa material balance of the technological process, definition of the main polluting substances on the basis of what calculation of masses and concentration of the substances in sewage is 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, whatimpacteach process has onthe enterprise in the general sewage pollution. The system helps to determine the concentration of those substances in wastewater whichis not defined with the use of laboratory measures. Though,complete replacement of the laboratory control over sewage is not the purpose of the suggested system, it can add its results, because single tests on wastewater are not always indicative.

The objective of the research is 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:

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

The suggested system can be used at any food industry enterprise, but the example with all calculations is provided for the MykolaivBranch of "SUNInBev Ukraine" which became the object of research. The formation process of wastewater in the enterprise has been selected as the scope of research.

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

Main part

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 asimple measurement of sewage composition is taken, and when their structure is controlled at each production phase. Such system allows presentation of a positive impact of the plant on the environment, to estimate a 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 environment. There is a possibility of forecasting the qualitative and quantitative composition of sewage for any period in all divisions of the enterprise, which essentially supplementsthe laboratory methods of analysis, which not always are indicative, demand time, not all elements of a substance can bedefined.

For modernization of the wastewater control system there was a need of studying of the technological scheme of production. Analysis of thebeer production process in Mykolaiv Branch of "SUN InBev Ukraine" showed the main points of wastewater formation:

1. Reception of barley and malt;no use of chemicals and dumping of industrial sewage.
2. Barley crushing;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.

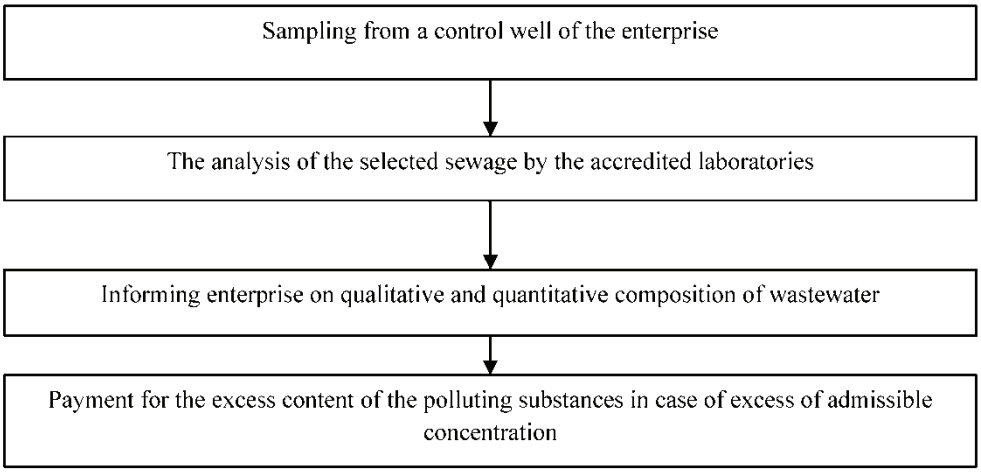

Figure 1. The present wastewater control system in Ukraine

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 (Kovalevskaya, 1993).
   - 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 (Kolotyloet al.,2003).
   - separation from hop and cooling (Kovalevskaya, 1993).

   The sewage containing organic pollution, particles of diatomaceous earth, pellets and the dissolved components of detergents are respectively formed.
5. Mash is fermented.Special races of cultural yeast are used in brewing which ferments mash with formation of alcohol and carbon dioxide (Kunce, 2001). Fermentation takes place in two stages:
   - main fermentation. It is characterized by intensity of the process and fermentation of the most part of sugars (a 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 by the kizelgurfilters. Separations are usedfor beer which is spilled in barrels.At this stage water and detergents are used, the sewage containing components of the used means and organic pollution is formed (Kunce, 2001).
7. Preparation of a container and beerbarreling: water for washing a container with the use of the aggressive washing substances. The sewage were sated with various aggressive substances from the remains of labels gets to the sewage, flew down and so forth.

The 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 others are used. Insignificant pollution of very low concentration gets to sewage.

8. The department of logistics: low-quality beer merges in the sewerage that means high organic pollution.
9. Auxiliary production: water is also used for economic domestic needs.

The analysis, which was carried out, allows determination of the main divisions which pollute sewage such asdepartment 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 thesewage. Thebrewing 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-stabicipOXI; 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-ansepCIP.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 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 showerssubstandard products.

The chemical compositionof means which are used by enterprise were studied. For example, detergent P3-topax56is 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 $O_2 \cdot g^{-1}$. Similar resultswere 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 stagesis made for modernization of wastewater control system. We will present 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 interestedin 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 particulartime.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 ofthe 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 (Muravyov, 2004);
– phosphates are a part of some means;
– surfactants are part of some means;

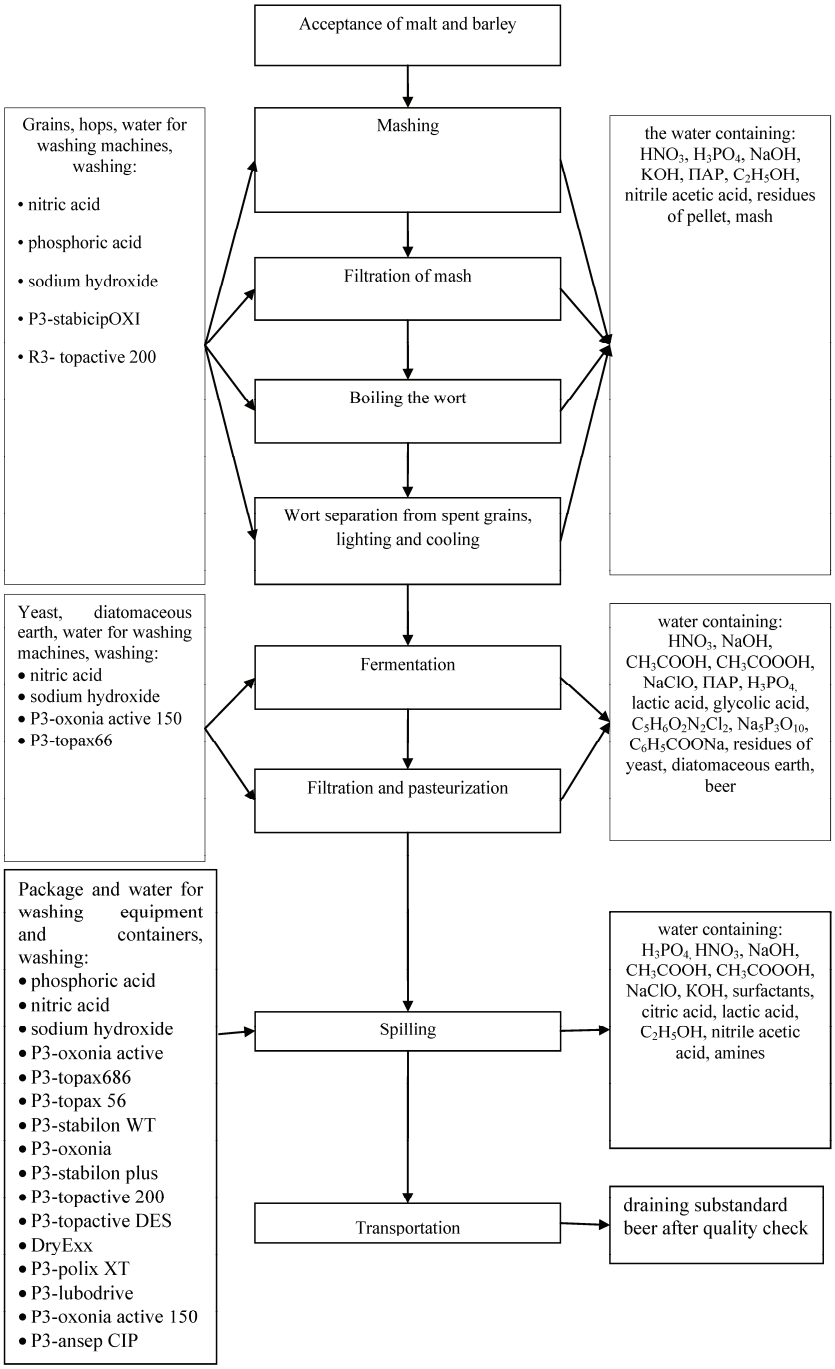

Figure 2. Scheme of wastewater formation

– nitrogen content calculated by the nitrate form, as a 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 it can change 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.

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

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

$$m(pollu\ \tan t) = w(pollu\ \tan t\_in\_mean) \cdot m(mean) = \\ = \frac{M(pollu\ \tan t\_in\_subs\ \tan ce)}{M(subs\ \tan ce)} \cdot w(subs\ \tan ce\_in\_mean) \cdot m(mean),\ g \quad (1)$$

where:

M (pollutant in substance) – the molar mass of the pollutant in the substance, ($g \cdot mol^{-1}$)

M (substance) – the molar mass of the substance, ($g \cdot mol^{-1}$)

w (substance in mean) –the mass fraction of substance containing pollutants in means

m (mean) – the mass of the used means, (g)

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 each substance which contains phosphates. In the brewing department of phosphates there are 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:

$$m(PO_4^{3-} in\ P3\text{ - trimet a DUO}) = \frac{95\,kg/kmol}{98\,kg/kmol} \cdot 0{,}4 \cdot 525\,kg = 203{,}57\,kg$$

COD indicator for each means is given in mg $O_2 \cdot g^{-1}$, and the mass of means is considered in kg. Therefore COD for various means is determined by a formula 2:

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

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

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

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) To determine the total mass of a particular pollutant in the department and across the entireenterprise according to 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:

$$c(pollu\tan t) = \frac{\sum m(pollu\tan t)\cdot 1000}{V(wastewater)}, g\cdot m^{-3} \quad (5)$$

where:

Σm (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 14779 m^3):

$$c(PO_4^{3-}) = \frac{482{,}97kg\cdot 1000}{14779m^3} = 32{,}67g\cdot m^{-3}$$

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 in those departments which exceed the norms of use and taking measures for rapid response to reduce theimpact on the environment.For this purpose in calculation we will define not only the actual volume of use of means, but also the plannedone. For determination of the planned mass of use of a certain means we use the formula 6:

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

where:

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, $V_{planned.bear}$=78930hl:

$$m_{planned}(HNO_3) = 0{,}07kg\cdot hl^{-1}\cdot 78930ch=5525{,}1kg$$

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

$$costs = \frac{m_{actual}}{V_{actual.beer}}, \quad (7)$$

where:

m_{actual}– the actual mass of the used means, (kg)

$V_{actualbeer}$– 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 with admissible concentration not to be relied by single analyses which often are unclear, 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.

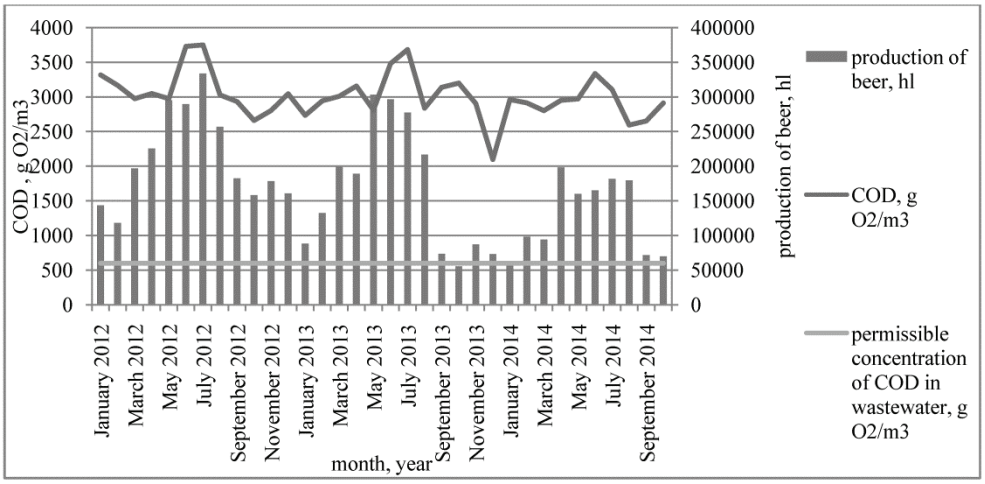

Figure3. Calculated COD of wastewater

Since the proposed system of calculation of concentration of the pollutants is the additional effective instrument of the wastewater control system of the plant it allows identification of the processes that cause the most pollution. This system allows making decisions on reduction of the influence on environment by change or improvement of production process, replacing some means (fig. 7).

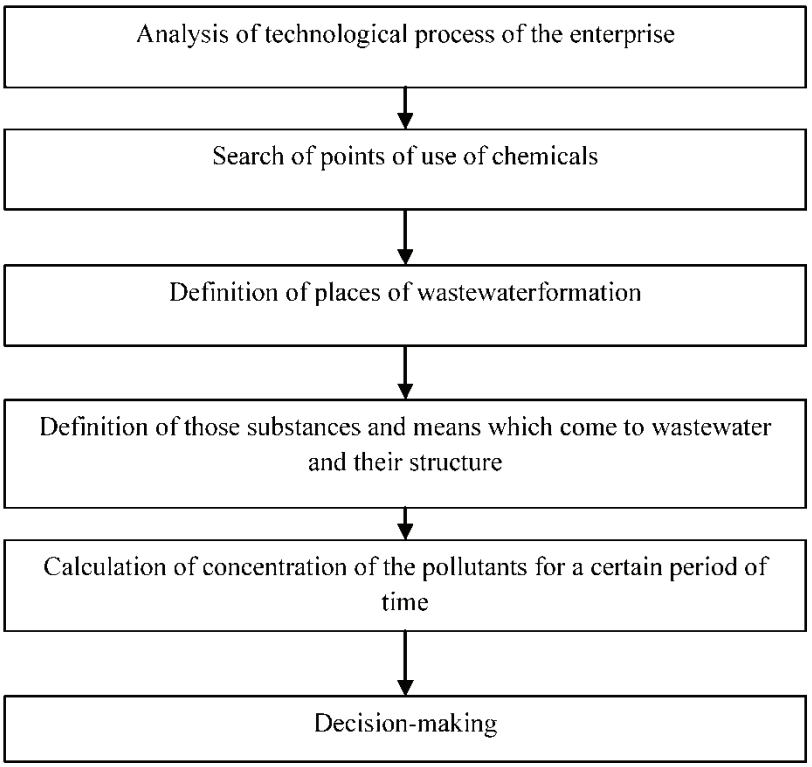

Figure 7. The offered control system of wastewater formation

Conclusions

The main problem of the brewing industry plantsis the use of a great amount of water and formation of 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 are investigatedonce a week, and then it is determined whether the company complies with the standards, but this approach is not quite correct.Therefore, there is a needto carry out a continuous wastewater control by 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 stageof the process on which the most wastewater isgenerated and which unit is the biggest polluter; the result is valid, not single concentration of pollutants;

- predicting: by data of the usednormsofmeans 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 cause the greatest pollution, it is possible to make operational decisions on reduction of the 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.When local treatment facilities of biological type operate, there is a need of careful control over thequalitative and quantitative composition of the wastewater. Therefore, the given control system is adapted for daily calculations of the pollutants concentration in sewage. This allows making quick decisions on the treatment of specific wastewater, which significantly reduces the negative impact on the environment.

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MODERNIZACJA SYSTEMU KONTROLI ŚCIEKÓW W PRZEMYŚLE SPOŻYWCZYM

Streszczenie. W celu zminimalizowania wpływu ścieków pochodzących z przedsiębiorstw na środowisko podejmuje się kroki związane z ulepszeniem systemu monitorowania na każdym etapie procesu technologicznego. Proponuje się nowe narzędzie polegające na obliczaniu stężenia zanieczyszczeń w systemie monitorowania na podstawie określania bilansu masy procesu technologicznego produkcji, które pozwoli na przewidywanie składu jakościowego i ilościowego ścieków w określonym okresie czasu. System może być stosowany w każdym przedsiębiorstwie, ale przykład obliczeń został podany dla oddziału Mykolaiv przedsiębiorstwa „SUN InBevUkraine", które jest obiektem badań. Zakresem badań objęto proces tworzenia się ścieków w przedsiębiorstwie. Wykonanie zadań pociągnęło za sobą metody naukowe takie jak: analiza, synteza, systematyzacja i generalizacja podczas przeglądu odpowiedniej literatury dotyczącej przedmiotu badań; modelowania, formalizacji, porównania – przy określaniu schematu obliczeń stężenia zanieczyszczeń w ściekach; kontrola – podczas badania schematu technologicznego produkcji; oraz metody związane z matematycznym przetwarzaniem danych w programie MS Excel.

Słowa kluczowe: ścieki, zanieczyszczenia, bilans masy, kontrola, zarządzanie, przemysł spożywczy