SWOT analysis of industrial wastewater

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Abstract. The proposed SWOT-based analysis paper studies the treatment process of industrial wastewater. Based on the analysis results, the author presented an information field of "strengths and weaknesses" of the enterprise, showing the operational efficiency (or inefficiency) of the wastewater treatment facilities for various pollutions. It is shown that a system approach with the combination of quantitative and qualitative analyses of the object under examination should be used in decision making. The recommendations are given concerning the elimination of wastewater treatment defaults and leading to the environment safety of water bodies. The paper demonstrated a condition for discharging treated wastewater depending on the nature of its use and the content of the maximum permissible concentrations in treated wastewater.

1. Introduction
At present a SWOT analysis [1] is being successfully used in many fields of human activities. A SWOT analysis (English for Strengths – Weaknesses – Opportunities – Threats), which is one of the forms of diagnostics, for example, of a controlled system, consists in revealing the strengths and weaknesses of the object and ultimately makes it possible to improve and optimize the system in the presence of both internal and external negative factors.

As a rule, a flow of industrial wastewater [2] generated as a result of technological processes during the production or extraction of minerals causes a variety of undesirable consequences: clogging of the water body with insoluble substances, deterioration of the physical and chemical properties of water and oxygen regimen, increase in the organic substance content, poisoning of the living organisms by toxic substances, and, etc. [3]. Thus, the necessary condition for improvement of the efficiency of wastewater treatment consists in correct scientifically based selection of the most rational purification methods in each particular case.

Conceptual issues associated with industrial wastewater treatment are discussed in [4,5], and [6].

Nowadays, there are three main methods of industrial wastewater treatment [7]. They are mechanical, physical-and-chemical, and biological one. Depending on the nature of industrial wastewater, pollution degree, and type of pollutants, the methods are based on different impact procedures that contribute to the improvement of wastewater treatment.

In a number of cases, in order to diagnose a water body into which industrial wastewater treated (untreated or treated poorly) flows, one requires the latest information on the condition of the water body. And, in case of its non-satisfactory quality, urgent technical and organizational measures should be applied.
2. Theoretical study
The SWOT-based paper examines the treatment process of industrial wastewater. In this case the SWOT analysis provides for a multi-parameter analysis (monitoring) of the water which allows of forming a matrix of the strengths and weaknesses of the enterprise operation and identifying the factors determining the efficiency or inefficiency of the enterprise in terms of the water pollution.

Let an ecologist carrying out an analysis of a water body with due regard for the degree of wastewater treatment obtain a matrix of strengths and weaknesses and opportunities and threats (table 1).

Table 1. An example of a SWOT analysis for industrial wastewater treatment.

| Strengths                                           | Opportunities to reduce the pollution                      |
|-----------------------------------------------------|------------------------------------------------------------|
| 1. The industrial wastewater discharged into the water body contains no more than 15% of suspended solids. | 1. The enterprise is equipped with reliable and efficient sand traps and decanters. |
| 2. Ninety percent of dissolved impurities are removed from the wastewater. | 2. Effective application of coagulation and flocculation methods. |
| 3. The wastewater contains 10% of organic substances. | 3. Effective utilization of aerobic microorganisms, for whom organic substances serve as a source of nutrition. |

| Weaknesses                                           | Negative factors                                          |
|-----------------------------------------------------|------------------------------------------------------------|
| 1. The content of floating impurities in the wastewater is 65%. | 1. Insufficiently effective operation of oil traps. |
| 2. The wastewater contains 70% of insoluble compounds. | 2. Ineffectiveness of the treatment and sanitation of the wastewater based on the methods of neutralization and oxidation. |
| 3. The content of colloidal and fine particles in the wastewater is more than 85%. | 3. The amount of reagents added to the wastewater is not sufficient to flocculate the particles. |

Judging from the results of the SWOT analysis, the ecologist may make the following decisions:
- to raise the question of a partial replacement of the oil traps with more efficient ones;
- to introduce more effective reagents into the neutralization and oxidation of the wastewater;
- to increase the efficiency by adding special additional substances to the wastewater;
- to equip the wastewater treatment facilities with devices providing operational control over the treatment degree.

As one can see, a SWOT analysis is an important intermediate link between control and diagnostics, on the one hand, and decision making and management correction, on the other hand. Having received an information field and having experience of acting in similar situations, an operator will always be able to make decisions that are adequate in the current situation and implement them in the existing conditions to obtain predictable results.

It seems clear that a SWOT analysis does not exist isolated. On the one hand, it is an innovative management component [8] in addition to monitoring and diagnostics and decision making and management correction. On the other hand, the results of monitoring and diagnostics are inputs to the analysis, and its results, in turn, provide inputs to decision making [9].

Indeed, determination of strengths and weaknesses of system operation is feasible only on the basis of quantitative assessment and qualitative diagnostics of a system condition. Formation of an information field is grounded on the decision rules. Let S be a multiplier of the parameters obtained as a result of the monitoring and diagnostics and R be a set of decision rules. Then \( Q = f(S,R) \) and \( W = g(S,R) \), where \( Q \) and \( W \) are sets of pieces of information and should be referred to Strengths and Weaknesses. The output of the SWOT analysis \( J = QW \) appears to be an input for decision making.

The results of the SWOT analysis of industrial wastewater showing the efficiency (or inefficiency) of operation of the wastewater treatment facilities can be further used to justify the choice of conditions and possibilities for releasing the wastewater into a water body, taking into account the regulatory act "Rules for the Protection of Surface Waters from Pollution by Wastewater". These
Rules establish two types of standards that the quality of water in a water body must comply with in accordance with the nature of its use (for drinking, or cultural and domestic use, or for fisheries purposes), as well as the maximum permissible concentrations of various substances in water, which are used as input data for determination of the conditions for discharging wastewater. In some cases (according to the laws), depending on the progress of the wastewater treatment, the water body type, and the further use of treated wastewater in the industrial water supply, an additional measure such as post-treatment of wastewater [10] can be carried out.

In general, the industrial wastewater treatment must be conducted with account of the sanitary rules [11] that establish the sanitary and epidemiological requirements (including safety criteria and (or) harmlessness of human environment factors, hygienic standards, and others), noncompliance of which poses risks to human life or health and creates a threat of diseases.

When several industrial enterprises discharge their wastewater at the same time, it is necessary to carry out a multifunctional diagnostics of the water body and, in case of its inconsistent sanitary condition, determine the source (or sources) of the pollution by a SWOT analysis. In other words, one needs to find out an enterprise (or enterprises) with strengths and weaknesses using the analysis.

Wastewater treatment, discharging it into water body, and decision making after a SWOT analysis can be regarded as a system [12], characterizing the ecological state of the water body. With this in view, it makes sense to perform a full study of the system combining a quantitative and qualitative analyses. The technological unity of quantitative and qualitative analyses provides for a unified technological research cycle for a complex system to which we can refer the "wastewater formation, treatment, diagnostics, and decision making" system. The significance of this approach consists in the fact that it allows of identifying disadvantages (advantages) of wastewater treatment and adjusting enterprise operation in the context of possible pollution of the water body as well as the ecological state of the water body itself. A comprehensive study of the water body should combine all the methods of a multiparametric analysis. In addition, all the types of a multiparametric analysis are performed on the basis of the same indicators characterizing the water body, i.e., the primary information proves to be general.

When carrying out a SWOT analysis of wastewater containing highly hazardous substances such as lead, mercury, and others, it is recommended to monitor the controlled environment on the basis of treatment techniques and methods with innovative technologies that ensure the maximum exclusion of these substances from the wastewater. If concentrations of these substances are allowable, one must strictly adhere to their content in treated water, taking into account their maximum permissible discharges (MPD) [13].

3. Practical relevance

In practice, the effectiveness of a SWOT analysis of wastewater depends largely on the nature and specifics of the industrial enterprise’s operation.

Cleaner production has acquired currency lately; it is normally taken to mean a technological strategy preventing from the environmental pollution and lowering the risk for humans to the minimum [14]. Speaking from the perspective of the products, cleaner production signifies the environment impact mitigation during the product life cycle, that is, from the extraction of raw materials to the disposal after using.

A human being should come closer to low-waste and resource-saving production in the course of activities [15]. Low-waste production involves the usage of raw material resources in the cycle including the consumption and means that the closed cycle can be realized at a territorial production level. All the raw material components must be incorporated in the industrial production. The greatest possible use of energy resources capacity must be provided with restriction of the second law of thermodynamics. The maintenance of the normal environmental operation and the existing ecological balance is required.

Nowadays, there is a method for definition of criteria referring industries to zero waste, low waste, and conventional. This method generally contains a coefficient of employment of material resources
(\(K_1\)), a coefficient of employment of energy resources (\(K_2\)), and a coefficient of compliance with ecological requirements (\(K_3\)). A zero waste coefficient (\(K_z\)) is defined as a function of \(K_1, K_2, \) and \(K_3\). For instance, in coal mining the zero waste coefficient [16] is computed using the following formula:

\[
K_z = 0.33(K_4 + K_5 + K_6),
\]

where \(K_4, \) \(K_5, \) and \(K_6\) are coefficients of employment of waste rocks formed during the mining operations, water derived during the coal extraction, and dust and mud wastes respectively.

In the chemical industry for determination of the zero waste coefficient \(K_z\) one should utilize the following formula:

\[
K_z = fK_mK_enK_ec,
\]

where \(f\) is a proportionality factor, \(K_m\) is a coefficient of employment of material resources, \(K_en\) is a coefficient of employment of energy resources, and \(K_ec\) is a coefficient of compliance with ecological requirements. In accordance with this method and depending on its capacity, production can be qualified as low-waste (\(K_z\) is not less than 0.8-0.9) or zero-waste (\(K_z\) is more than 0.95-0.98). Besides the quantitative estimation of wastes one must consider their toxic and hazard levels for the environment [17].

The development of zero-waste production is a long process requiring solution to a number of interrelated process, economic, organizational, psychological, and other problems.

When purified effluent has been discharged into a water body, the water body must be suitable for specific types of water use [18]. For comparative assessment of the aquatic medium different indices are applied; they allows of considering several polluting substances. The complex hydrochemical water pollution index (WPI) is the most common one. It is determined from the formula as follows [19]:

\[
WPI = 1 - \sum_{i=1}^{n} \frac{C_i}{TLV_i} = \frac{1}{6} \sum_{i=1}^{n} \frac{C_i}{TLV_i},
\]

where \(n\) is the number of parameters used in the index calculation, \(C_i\) is the level of chemical substance in the water, mg/l, \(TLV_i\) is the threshold limit value of chemical substance in the water, mg/l.

The water pollution index (WPI) is usually calculated by six or seven hydrochemical parameters including essential factors such as the dissolved oxygen level (O_2), the hydrogen ion exponent, pH, and the biological oxygen demand BOD_5. The water quality must meet the Sanitary Regulations and Standards [20] in all cases. The water must be safe in respect to epidemiology and radiation, clean chemically, and have correct organoleptic properties.

4. Conclusion

The results of the study can be used to ensure the environmental safety of water bodies in the human interaction with these environments and to create wastewater treatment facilities systems with their operational control.

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