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Development of the Basic Principles of Ecological Safety of Operating Textile Enterprises

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Abstract

For the sustainable development of the environment the paper proposes the basic principles of ecological safety which can be achieved through the creation of the next enabling environments to direct the enterprise operation to the completely integrated use of natural resources. The proposed basic principles of environmental safety, an enabling environment aimed to the full comprehensive utilization of natural resources, are based on the regulatory requirements and does not contradict the modern laws of the Republic of Kazakhstan. The paper sets criteria for assessing the environmental safety of the finishing enterprise. For it the processes of textile finishing, water treatment and re-circulating water supply technologies were considered from the perspective of a single work cycle, which is from the technical-environmental and ecological-economic perspective.

Keywords - Industrial enterprises, environmental safety, textile enterprises, groundwater, environmental characteristics.

I. INTRODUCTION

Environmental cleanliness requirements for the functioning of industrial enterprises are dictated by the need to exclude the negative impact on the components of geo- and biosphere [1]. In recent years, it was developed a lot of processes which practically eliminate the emission of pollutants into the environment and may be called as waste-free or low-waste technologies [2;3]. However, many environmental studies carried out in developed countries, have shown that the construction of treatment plants requires considerable capital cost (sometimes costs size is up to 50% of the value of major facilities), and it is impossible to solve the problem of environmental pollution prevention completely [4]. In this regard, the impact of economic activity on the environment will continue to manifest itself in a variety of consequences that directly affect environmental safety.

«Environmental Safety» - a set of actions, states and processes which does not lead to essential damage to the environment and to humanity directly or indirectly. The environmental safety reviewed from the perspective of a single enterprise is a system of existing enterprise interaction with environment, guaranteeing stable operation of the environment components on the basis of strict compliance with environmental regulations.

For the sustainable development of the environment the paper proposes the basic principles of ecological safety which can be achieved through the creation of the next enabling environments to direct the enterprise operation to the completely integrated use of natural resources [5; 6]:

1) Common management methodology of environment protection works aimed to the economic justification of solutions adapted to the region of enterprise location;
2) System of ecological and economic standards for the evaluation of the technological processes used at the enterprises, which determines the level of rational use of natural resources;
3) The formation of enterprise environmental expenditure items in order to invest in the new water treatment technologies based on a common methodology of enterprise economic solutions;
4) Organization of flexible payment systems for use of natural resources and the environment, which allows the company to improve and optimize production processes;
5) Organization of optimal ecological and economical technology of cleaning and recycling of waste products or getting the product from it;
6) Increasing the amount of high-quality finished products output from a unit of raw materials, leading to rising prices curb.

The proposed basic principles of environmental safety, an enabling environment aimed to the full comprehensive utilization of natural resources, are based on the regulatory requirements and does not contradict the laws of the Republic of Kazakhstan «On Environmental Protection», «On Ecological Expertise» and «Water Code of Kazakhstan».

Now let’s study the environmental safety principles with the example of the developed complex technology of cleaning and re-circulating water supply of finishing enterprises Almaty [7; 8]:

- in the implementation of the first paragraph of the main enterprise environmental safety principle: it is developed a scheme of the water balance of the finishing of the enterprise and a complex technology of the enterprise sewage treatment ;
- in the implementation of the second paragraph: it is developed the regulations for quality of the re-

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circulating water used in the process of textile materials finishing;

- in the implementation of the third paragraph: it is defined an ecological and economic efficiency of the implementation of water saving technologies in finishing plants;
- in the implementation of the fourth paragraph: this paragraph is carried out in the framework of the standard fees for use of natural resources and the environment, established by the regional offices of the Ministry of biological resources of environmental protection;
- in the implementation of the fifth paragraph: it is proposed the technology of processing finishing industries sewage sludge;
- in the implementation of the sixth paragraph: it is developed efficient technology of cleaning and re-circulating water supply of finishing enterprises leading to an increase of output due to the disposal of waste water [9].

As a result, the task - reduction of anthropogenic load and bring it to the level of environmental safety by reducing the release of harmful substances into the environment made by enterprises of light industry - can be determined as decided by the creation of water re-circulating system on the finishing enterprises [10].

II. CRITERIA FOR ASSESSING THE ENVIRONMENTAL SAFETY OF THE PROPOSED SOLUTIONS

For the practical implementation of the basic principles of ecological security of the enterprise it was first necessary to define our criteria for evaluating ecological safety and proposed technological solutions. According to different opinions [11], this problem can be solved from the viewpoint of a single technological cycle of the enterprise, that is technical-environmental and ecological-economic viewpoint.

To assess the environmental effectiveness of a particular technological cycle it is used the material balance of the enterprise:

$$M_{mm.} + M_{am.} = M_{fp} + M_w \quad (1)$$

$$M_w = M_w^I + M_w^{II} \quad (2)$$

Where: Mmm., Mam. - accordingly the weight of the main and auxiliary raw materials;

Mfp - the mass of the finished product;

Mw - waste mass;

M_w^I - reclaimed waste products;

M_w^{II} - waste, emitted to the environment (uncaptured waste).

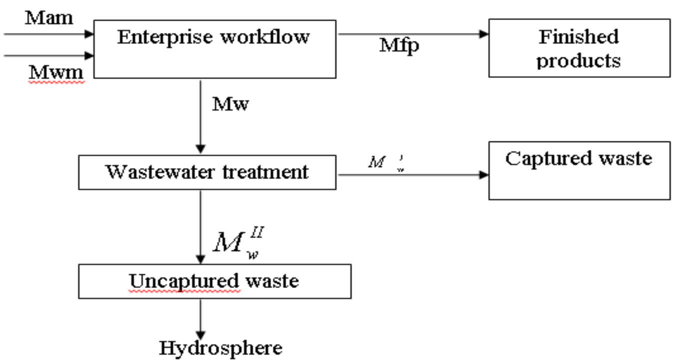

Fig. 1. Scheme of the enterprise work cycle

From Figure 1 it follows that if we introduce the τ treatment facilities trapping coefficient, which shows the effectiveness of its work, we take the next:

$$M_w^I = \tau M_w; \quad M_w^{II} = (1-\tau) M_w \quad (3)$$

To assess the impact of work cycle on the environment we introduce Kie coefficient which is determined as [6]:

$$K_{ie} = \frac{Mmpv}{M_w^{II}} \quad (4)$$

Where: Mmpv - weight of normalized maximally permissible values of harmful substances emitted to the environment. It includes the MPC or MPE of pollutants.

We introduce the following coefficients for the evaluation of the production cycle from the perspective of engineering and technology:

$$K_{pc} = \frac{Ga}{Gp}; \quad K_{rm} = \frac{M_{fp}}{M_{mm} + M_{am}} \quad (5)$$

Where: Kpc - production capacity using coefficient;

Krm - raw materials using coefficient;

Ga, Gp, respectively the actual and planned capacity of the work cycle.

After the foregoing we propose technical-ecological (K) coefficient characterizing the level of the work cycle rational operation:

$$K = K_{pc} \cdot K_{rm} \cdot \tau \cdot K_{ie} \quad (6)$$

Here production capacity using coefficient is always lim $K_{pc} \to 1$. Raw materials using coefficient characterizing the process yield is lim $K_{rm} \to 1$ too. But always in real conditions $K_{rm} < 1$. Coefficient characterizing the impact of work cycle on the environment is always lim $K_{ie} \to 1$ too. Then, in the ideal case, technical-ecological coefficient characterizing the level of the work cycle rational operation is lim $K \to 1$ too. The physical meaning of K value is the degree (level) of the rational use of natural resources.

International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 9 (2019), pp. 1445-1451

For evaluation of ecological and economic level of the work cycle operation we introduce the following coefficient:

$$R = K \cdot C_{pr} \quad (7)$$

Where: Cpr - the cost of one unit production, tg./ t.

The physical sense of the value of R is to express a specific proportion of enterprise rational expenses for one production unit. The R magnitude can be applied to the operational expert evaluation of existing work process or work cycle status. The proposed formula puts environmental and technological works in equal economic situation, blurring their distinction from the production point of view. For example, the growth of environmental facilities costs for appropriate activities of a particular process should be limited to a specific ecological and economic condition and directly associated with the minimum level of production efficiency. If you change its optimum it is necessary to change the process technology.

Now, in the present scheme we give technical-environmental and ecological-economic assessment of the work cycle of textile materials finishing.

Initial data for calculating K, R coefficients are shown in Table 1 at the current position; in table 3 they are shown in case of finishing enterprise common wastewater drain, in Table 5 they are shown in case of separate cleaning of weakly and heavily soiled wastewater streams of finishing enterprise.

Table 1. Data for calculation technical and environmental, ecological and economic levels of the finishing technological cycles

Indicators	Units	Value
Output product value: - planned Gp - actual Ga	 tg/cm tg/cm	 4.00 3.82
Costs Cpr	thousand tg / t	464.59
Costs: - main raw materials Mmm - auxiliary raw materials Mam	 tg/cm tg/cm	 3.95 2.46
Salable (finished) products value Mfp	tg/cm	3.77
Waste value: a) in the sewers - not captured - captured b) solid industrial waste (flaps by weight,scraps of fabric, tearing seams)	 tg/cm tg/cm tg/cm	 1.57 0.84 0,053
Total weight of waste: a) emitted into the environment b) captured waste	 tg/cm tg/cm	 1,623 0.84

In the paper the results of calculation of technical-economic (K) and ecological-economic (R) functioning levels of textile materials finishing technological cycle are shown in Table 2.

Table 2. The value of the coefficients K and R, characterizing the level of the finishing technological cycle

Indicators	Value
Coefficient of production capacity utilization, Kpc	0,955
Coefficient of raw materials utilization, Krm	0.59
Coefficient characterizing the level of impact of the technological cycle on the environment, Kie	0.93
The coefficient of capture of the treatment plant, τ	0.35
Coefficient characterizing the technical and ecological level of work cycle operation , K	0.183
Coefficient characterizing the ecological and economic level of work cycle operation, R	85.02

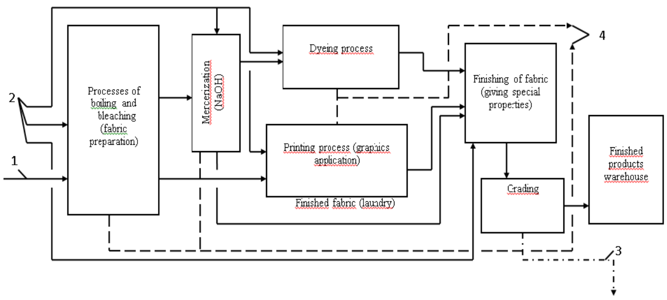

Fig. 2. Balance scheme of the technological cycle of textile materials finishing. Note: 1 - base material (crude fabric); 2 - auxiliary materials (dyes, textile auxiliaries, synthetic surfactants and finishing agents, etc.); 3 - solid industrial waste (flaps by weight, scraps of fabric, tearing seams, etc.); 4 - the waste coming into the waste water (dyes, textile auxiliaries, detergents and finishing agents).

Calculation results of feasibility (K) and ecological and economic (R) levels of the technological cycle of finishing textile materials in the purification of the total flow of wastewater are shown in Table 3.

Table 3. The data for the calculation of technical-environmental and ecological-economic levels of the finishing work cycle for the wastewater common drain cleaning.

Indicators	Units	Value
Output product value: - planned Gp - actual Gf	 tg/cm tg/cm	 4.00 3.82
Costs Cpr	thousand tg/t	464.59
Costs: - main raw materials Mmm - auxiliary raw materials Mam	 tg/cm tg/cm	 3.9 2.39
Salable (finished) products value Mfp	tg/cm	3.77

Indicators	Units	Value
Waste value:		
a) in the sewers		
- not captured	tg/cm	0.6
- captured	tg/cm	1.81
b) solid industrial waste (flaps by weight,scraps of fabric, tearing seams)	tg/cm	0,053
Total weight of waste:		
a) emitted into the environment	tg/cm	0.653
b) captured waste	tg/cm	1.81

The results of calculation of technical-economic (K) and ecological-economic (R) levels of the textile materials finishing work cycle for separate cleaning of weakly and heavily polluted wastewater streams are shown in Table 4 and Table 5.

Table 4. Data for calculation of technical-environmental and ecological-economic levels of the finishing work cycle for separate wastewater cleaning.

Indicators	Units	Value
Output product value:		
- planned Gp	tg/cm	4.00
- actual Gf	tg/cm	3.82
Costs Cpr	thousand tg / t	464.59
Costs:		
- main raw materials Mmm	tg/cm	3.85
- auxiliary raw materials Mam	tg/cm	2.25
Salable (finished) products value Mfp	tg/cm	3.77
Waste value:		
a) to the sewer:		
weakly polluted stream:		
- not captured	tg/cm	-
- captured	tg/cm	1.32
Heavily polluted stream:		
- not captured	tg/cm	0.27
- captured	tg/cm	0.82
b) solid industrial waste (flaps by weight,scraps of fabric, tearing seams)	tg/cm	0,053
Total weight of waste:		
a) emitted into the environment	tg/cm	0.323
b) captured waste	tg/cm	2.14

Table 5. The value of the coefficients K and R, characterizing the level of the finishing work cycle for separate wastewater cleaning.

Indicators	Value
Coefficient of production capacity utilization, Kpc	0,955
Coefficient of raw materials utilization, Krm	0.62
Coefficient characterizing the level of impact of the technological cycle on the environment, Kie	0.99
Coefficient of capture of the treatment plant, τ	0.9
Coefficient characterizing the technical and ecological level of work cycle operation, K	0.53
Coefficient characterizing the ecological and economic level of work cycle operation, R	246.23

III. METHOD OF CALCULATING OF THE POLLUTION IMPACT ON THE HYDROSPHERE

Reducing of the anthropogenic impact on the environment, sewer network and treatment facilities of the city and on further water basins is possible in case of further improvement of the existing environment quality criteria system [11]. The main normalized quality indicator of water basins is unitary Republic values of the pollutants emission maximum permissible concentration (MPC), which are calculated on the basis of different maximum allowable value of emission of the same contaminants into water basins for different regions. This is due to the existence of different conditional biocapacity of the region, depending on the degree of industrial development [10]. Therefore, during the event of environmental safety, aimed at the preserving of biopotential of specific region, it is necessary to have a specific application of environment evaluation criteria which is different from unitary pollutant emission MPC. Values of MPC for pollutants emitted into the sewer network of different cities are various.

For example, the MPC value of emission of finishing enterprise wastes emitted into the sewer network of Almaty city is shown in earlier papers [11].

However, examination of the state of the environment, based on the MPC and various SanPiNs (rules and regulations of water protection, sanitary protection zone, land acquisition, etc.), does not provide an exhaustive response to the modification or reaction of the environment state.

In order to guarantee protection of biopotential it is necessary to consider not only the emission MPC value reset as the criteria of direct exposure through water, food, air, and so on, but also the response for contamination of the ecosystem through criteria of benign productive state of the natural environment itself. So we need the mechanism which would allow obtaining an ecological response to the impact of the natural environment coupled with economic incentives [12]. The reaction of the environment or the response to man-made emissions is shown in the paper for the most vulnerable biological object or group of such ones and is expressed in the

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form of an integrated assessment. Consideration of economic incentives with environmental activities is carried out by introducing the coefficient of ecological-economic conditions of the enterprise work cycle operation [13].

To assess the environmental safety of the enterprise work we proposed work cycle environmental safety index:

$$K_{esi} = \frac{\varphi^{\phi}}{m} \cdot 100\% \qquad (8)$$

where: φ^{ϕ} - background or threshold response, depending on the ecological status of the region;

m - change of state of the environment, $m = \varphi^{\Phi} + \Delta\varphi$;

Here, the change of state of the environment m is a function of the background environmental indicators, ie:

$$m = f(\varphi^{\Phi} + \Delta\varphi) \qquad (9)$$

where: φ^{Φ} - the background environment indicator;

Δ - change of the background indicator.

When $m = \varphi^{\Phi} = \varphi^{tre}$ - the technological impact is reversible;

$m = (\varphi^{\Phi} + \Delta\varphi) > \varphi^{tre}$ - environmentally dangerous state;

$m = (\varphi^{\Phi} - \Delta\varphi) < \varphi^{tre}$ - environmentally safe state;

φ^{tre} - threshold environment indicator.

Now, taking into account the MPE for the region and integrated environmental safety criteria, we will consider the method of calculating the impact of contamination on the hydrosphere on the example of existing finishing enterprise in Almaty.

We will assume that the work process used for the finishing of textile materials reached a practical limit on the use of mineral resources:

$$K_{rm} = \frac{M_{fp}}{M_{mm.} + M_{am}} = 3,77/6,1 = 0,62$$

Then, the reciprocal of the Krm, technological standard of resource consumption:

$$N_{\Pi}^{T} = \frac{1}{K_{rm}} = 1/0,62 = 1,61 \text{ t / t. of products}$$

The technological standard of waste output at the current position:

$$N_{01}^{T} = \frac{M_{w}^{11}}{M_{fp}} = 1,57/3,77 = 0,42 \text{ t / t. of products}$$

Technological standard of waste output in case of implementing the wastewater common drain cleaning scheme:

$$N_{02}^{T} = \frac{M_{w}^{11}}{M_{fp}} = 0,6/3,77 = 0,16 \text{ t / t. of products}$$

Technological standard of waste output in case of implementing the scheme of separate weakly and heavily polluted wastewater streams cleaning:

$$N_{03}^{T} = \frac{M_{w}^{11}}{M_{fp}} = 0,27/3,77 = 0,07 \text{ t / t. of products}$$

In this case, the value of the raw materials utilization coefficient Krm increased from 0.59 to 0.62, and the level of technical-environmental coefficient K increased from 0.18 to 0.53.

We define the normed threshold reduced concentration of pollutants discharged into the sewage system of Almaty in accordance with the following formula with respect to the concentration of suspended substances [2]:

$$C_r^{nor} = C_1^n + C_2^n \frac{MPC_1}{MPC_2} + C_3^n \frac{MPC_1}{MPC_3} + \ldots + C_n^n \frac{MPC_1}{MPC_n} \qquad (10)$$

C = 500 + 15 + 20 + 900 = 1775 mg / L

According to the finishing enterprise data we determine the actual reduced concentration of pollutants discharged by the enterprise into the sewage system of Almaty:

$$C_r^{act} = C_1^{act} + C_2^{act} \frac{MPC_1}{MPC_2} + C_3^{act} \frac{MPC_1}{MPC_3} + \ldots + C_n^{act} \frac{MPC_1}{MPC_n} \qquad (11)$$

C = 277.5 + 42 + 41 + 580 = 2469.7 mg / L

We define the reduced concentration (background) for re-circulating water of the enterprise:

$$C_{re}^{b} = C_1^{b} + C_2^{b} \frac{MPC_1}{MPC_2} + C_3^{b} \frac{MPC_1}{MPC_3} + \ldots C_n^{b} \frac{MPC_1}{MPC_n} \qquad (12)$$

C = 30 + 2 + 20 + 100 = 535.55 mg / L

According to the formula (8) we calculate environmental safety coefficient of the enterprise work cycle:

a) with respect to the threshold value of pollutant emission:

$$K_{es} = \frac{C_{re}^{tre}}{C_{re}^{act}} \cdot 100\% = \frac{1775}{2469,7} \cdot 100\% = 71,87\%$$

b) with respect to the background (clean) state of water basins

$$K_{es} = \frac{C_{re}^{b}}{C_{re}^{act}} \cdot 100\% = \frac{535,55}{2469,7} \cdot 100\% = 21,7\%$$

Figure 3 shows the dependence of the environmental safety coefficient Kieb from value of change of the environment state (m). It also shows that the water basins receiving wastewater are environmentally safe if the value of the pollutants concentrations is close to background one.

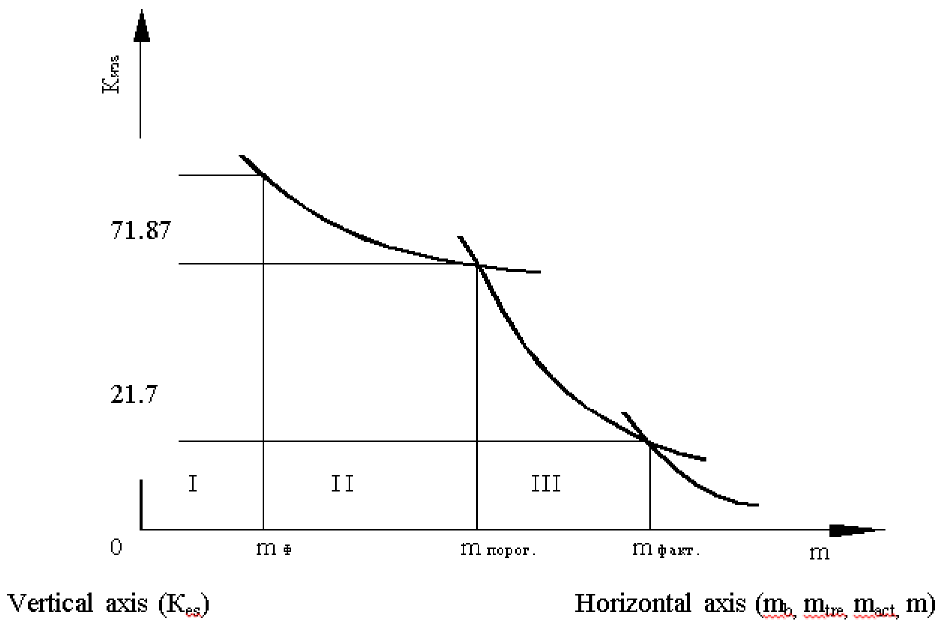

Fig. 3. Dependence of the form C_w=(w) for loess soil No. 4

IV. CONCLUSIONS

Reducing the level of anthropogenic impact and bringing it to the environmentally friendly level by creating a re-circulating water system on the finishing enterprises can be considered as relatively settled.

The paper sets criteria for assessing the environmental safety of the finishing enterprise. For it the processes of textile finishing, water treatment and re-circulating water supply technologies were considered from the perspective of a single work cycle, which is from the technical-environmental and ecological-economic perspective.

The evaluation of the environmental safety of the finishing enterprise is set. Calculation of the impact of contamination on the hydrosphere on the example of finishing enterprise in Almaty showed that water basins receiving wastewater are environmentally safe if the value of the pollutants concentrations is close to the background one.

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