9. Bhuiyan, M. I. H. Phosphorus recovery from wastewater through struvite formation in uidized bed reactors: a sustainable approach [Text] / M. I. H. Bhuiyan, D. S. Mavinic, F. A. Korch // Water Science and Technology. – 2008. – Vol. 57, Issue 2. – P. 175. doi: 10.2166/wst.2008.002
10. Gomelya, M. Low-waster ion exchangetechnology of extraction of nitrogen compouds from woter [Text] / M. Gomeya, G. Trohymenko, T. Shabliy // Eastern-European Journal of Enterprise Technologies. – 2016. – Vol. 3, Issue 10 (81). – P. 18–23. doi: 10.15587/1729-4061.2016.72328
11. Trus, I. N. Razdelenie khloridov I sulfatof pri ionoobmennom obezsolivanii vody [Text] / I. N. Trus, N. D. Gomelia, T. A. Shablii // Metalurgicheskaia i gornorudnaia promyshlennost. – 2014. – Issue 5. – P. 119–122.

UDC 628.54
DOI: 10.15587/1729-4061.2017.101388

ASSESSMENT OF THE POLLUTION DEGREE OF THE DNEPR RIVER AND DEVELOPMENT OF MEASURES FOR ITS DECREASE

A. Kasimov
Doctor of Technical Sciences, Professor, Deputy Director
Ukrainian Research Institute of Metals
State Enterprise «Ukrainian Scientific and Technical Center of Metallurgical Industry «Energostal»
Nauki ave., 9, Kharkiv, Ukraine, 61166
E-mail: kassimov@energostal.org.ua

I. Stalinska
PhD, Associate Professor
Department of Engineering of Urban Ecology*
E-mail: varnavskaia_irina@ukr.net

K. Sorokina
PhD, Associate Professor
Department of Water Supply, Sewerage and Water Treatment*
E-mail: kbsorokina@ukr.net
*O. M. Beketov National University of Urban Economy in Kharkiv
Marshal Bazhanov str., 17, Kharkiv, Ukraine, 61002

Розглянуто питання оцінки факторів, що впливають на забруднення поверхневих і ґрунтових вод промислових територій. Проаналізовано негативний вплив накопичувачів промислових стічних вод і шламів на стан водного басейну. Визначено об'єкти та суб'єкти впливу, наведені технологічні схеми очищення стоків і охарактеризовані види шкоди навколишньому природному середовищу з боку накопичувачів промислових стічних вод

Ключові слова: захист водного басейну, очищення стічних вод, важкі метали, утилізація шламів

Рассмотрены вопросы оценки факторов, влияющих на загрязнение поверхностных и грунтовых вод промышленных территорий. Проанализировано отрицательное воздействие накопителей промышленных сточных вод и шламов на состояние водного бассейна. Определены объекты и субъекты влияния, приведены технологические схемы очистки стоков и охарактеризованы виды ущерба окружающей природной среде со стороны накопителей промышленных сточных вод

Ключевые слова: защита водного бассейна, очистка сточных вод, тяжелые металлы, утилизация шламов

1. Introduction

The level of water pollution of such rivers as the Rhine, Danube, Elbe, gave the reason, in the twentieth century, to call them "gutters of Europe". On 17 March, 1992, under the aegis of the United Nations Economic Commission for Europe, in Helsinki (Finland), the "Convention on the Protection and Use of Transboundary Watercourses and International Lakes" ("Water Convention") was adopted.

This Convention serves as a mechanism for strengthening national measures and international cooperation aimed at achieving environmentally sound management and protection of transboundary surface and ground waters. It includes legislative norms for punishing and encouraging enterprises, which discharge industrial waste water (IWW) and sludge into rivers.

Industrialists have been interested in the fulfillment of the commission's instructions. For this purpose, new technologies were developed to reduce volumes of industrial waste water, flows of toxic filtrates from ponds of industrial waste water and sludge into the water basin.

A sufficiently effective way to prevent infiltration of industrial waste water is to arrange protective anti-filtration screens from polymer films (Fig. 1).

Fig. 1. Modern ways to prevent the flows of waste water from ponds

To implement the provisions of the "Water Convention", efforts for establishing and strengthening transboundary water cooperation in the countries of Eastern Europe, the Caucasus and Central Asia (EECCA) have been made. The Law on Ukraine's Accession to the Convention was adopted on 1 June, 1999 by the Verkhovna Rada (Parliament) of Ukraine and came into force on 23 June, 1999.

Currently, Ukraine faces the problems, similar to the ones that were solved in the industrialized countries of Europe to improve the environmental conditions of their water basin.

2. Literature review and problem statement

The pollution of water by toxic metals as a result of anthropogenic processes is of great concern all over the world. Pollutants in the water system are recycled as a result of physico-chemical and biological processes, creating the risk of adverse effects on human health, water, soil quality and crop yield. Researchers around the world focus their attention on the quantitative study of heavy metals in aquatic ecosystems [1].

In addition to the detection and quantitative analysis of the pollution content in water bodies and soils, assessment of unfavorable risks to human health is conducted [2]. The greatest levels of pollution and, as a result, a threat to public health, are noted in industrial zones with significant anthropogenic activities [3].

To assess the content of pollution in water bodies, including heavy metals, various methods and indicators have been proposed. Composite indicators (CIs) are increasingly used to measure and monitor environmental systems [4]. However, they are criticized for not taking into account the uncertainties and their frequent arbitrary nature. Composite indicators reveal trends in complex environmental systems for broader stakeholder groups, including the public and politicians.

To determine the general condition of quality of untreated and treated waste water, Wastewater Quality Index (WWQI) was proposed [5]. This index summarizes a large number of measured quality parameters in a single indicator of water quality, taking into account pre-established standards of quality limitation.

An attempt has been made to create an indicator of global parameters of wastewater treatment for assessment of environmental factors and sustainable development based on waste water treatment statistics for 183 countries [6]. However, the lack of consistent definitions, reporting protocols and centralized database on wastewater treatment is the main reason for many problems in the construction of comparable performance indicators.

The accumulation of heavy metals in river sediments due to contamination of surface water can be estimated using the metal index (MPI) and the metal pollution index (HPI) [7].

It is defined that it is insufficient treatment, continuous discharge of IWW and filtrate of their sludges that are a significant factor of negative impact on the environment and accumulation of toxic impurities in water bodies. A significant effect of waste water from tanneries, dye-chemical, metal-processing industries [8] was noted.

Understanding the sources and behavior pattern of heavy metals in river basins is critical to assessing the risks associated with impacts on humans and ecosystems. To estimate the spatial distribution of pollutants in river sediments, the geo-accumulation index (I_{geo}) can be used. Thus, the assessment of pollution of the Maba River (South China) was done and the negative impact of waste water discharge and tailing dumps of the metallurgical enterprise was investigated [9].

In Ukrainian practice, the problems of the environmental and economic assessment of consequences of placing storages of untreated IWW and sludges appeared only in recent years. In this connection, there are no really approved methods of such assessment. In addition, such storages are often anthropogenic deposits of heavy metals (HM), which require the establishment of enterprises to develop them.

In the basin of the Dnepr river, 3 main zones of pollution of surface and ground water, which are formed under the anthropogenic influence [10], were identified.

The first one is the zone where chemical and energy industries are located. Within its borders, the subzone of influence of oil refining enterprises – the basins of the Berezina, Orel, Sula and Psel rivers (Ukraine), and the subzone of influence of the food industry enterprises – Zhytomyr, Vinnitsa, Cherkassy, Sumy, Poltava and Kharkov regions (Ukraine) are assigned.

The second one is the zone of the mining and metallurgy complex – the basin of the middle stream of the Dnepr river. Here the subzone for the location of enterprises of the mining and metallurgy, and energy complexes is allotted – Krivorozhye, Nikopol-Marganetsky, Dnepropetrovsk, Dneprodzerzhynsk and Zaporozhye (Ukraine).

The basin of the Dnepr river has more than 350 storages, 279 of which are sludge ponds and 22 are tailing dumps, the rest are IWW ponds. The largest storages of of IWW and sludge effluents are located in the middle stream of the Dnepr river in Dnipropetrovsk, Dneprodzerzhynsk and West Donbass industrial and economic areas, which are approximately 75 % of the total IWW effluents [11]. They include storages of IWW and sludges of the Northern, Central, Ingulets, Southern and Novokrivorozhskiy ore-dressing and processing plants of Krivyi Rih, Poltava, Ordzhonikidze ore-dressing and processing plant, "Zaporizhstal", "Dneprovsky aluminum plant", etc. (Fig. 2, 3).

The third one is a zone with the developed irrigation farming in the South of Ukraine.

To protect the public and the environment from toxic effluents, pollution prevention, reduction of using toxic chemicals, restoration and enhancement of protection of all water bodies should be state policy [12]. Concerted actions are required for the safe use of toxic chemicals. Principles and practice of sustainable development will help to contain or eliminate the risks associated with chemical pollution.

To meet the increasingly stringent environmental requirements for removal of heavy metals from waste water, a wide range of treatment technologies can be used, such as chemical deposition, coagulation, flotation, ion exchange and membrane filtration [13].

Fig. 2. A general view of the depleted pit of PJSC "ArcelorMittal Kryvyi Rih" (Ukraine) with a depth of 300 m

Fig. 3. Panorama of the sludge pond of the "Nikolaev Alumina Refinery"

In the European Union, water reuse is a common practice, both in environmental protection, and as one of the most effective solutions to the water deficit issue [14]. The implementation of technologies to reduce waste water forming can effectively decrease the overall demand for fresh water in water-based processes and subsequently reduce the amount of the generated waste water [15]. The progressive technologies for decontamination of waste water sediments, including those containing heavy metals [16], are developed and implemented.

3. The purpose and tasks of the study

The purpose of the study is to determine the degree of the negative effect of IWW and sludge ponds on the water basin of the Dnepr river. Based on conducted studies, it is necessary to propose measures to improve the water quality of the main water supply source in the area of one of the largest metallurgical enterprises in Ukraine – "Zaporizhstal".

To achieve this purpose, the following tasks should be solved:

– to monitor water quality in water bodies of the Dnepr river with definition of the most common pollutants;

– to determine the average annual concentrations of pollutants in the period 2011–2013 under the influence of industrial, communal and agricultural facilities, etc.;

– to prove technical solutions to reduce the negative impact of a sludge pond of a large metallurgical plant on the water basin of the Dnepr river.

4. Materials and methods for assessing the degree of the negative impact of IWW and sludge ponds on the environment

4. 1. Principal method of determining the degree of the negative impact of the facility on the environment

When developing technologies for the recovery of valuable components from IWW and sludge, it is necessary to estimate the degree of contamination of the environment by effluents and industrial wastes, which allows determining the damage caused to it.

Indicators of environmental pollution are chemical composition of raw materials, products of enterprises, taking into account regional background, as well as the resulting effluents and sludges. The objects of damage are the surface atmosphere, land areas, water bodies within pollution dispersion in the range of maximum permissible concentrations (MPC), natural landscapes, etc.

The following types of damage are identified:

– potential – theoretical size of the damage caused to the objects of the environment in the absence of environmental protection measures;

– prevented – avoided or reduced damage taking into account compensatory and liquidation activities in the implementation of environmental measures;

– residual – the damage that has remained after the implementation of environmental measures, compensation and liquidation of damage caused to the environment, rehabilitation measures, etc.

The degree of the negative impact of enterprises on the environment is determined by their sizes. There are objects with low, medium and high intensity of negative impact, which correspond to the values of the coefficient k_1 (Table 1).

The degree of danger of accumulated substances is determined by the formula:

$$D = 5 - (Dang - 0{,}25 \cdot N), \quad (1)$$

where D – degree of their danger; Dang – hazard class of the most dangerous component; N – number of additional hazard factors.

Table 1

Coefficients of intensity of impact of industrial waste water pond on the environment

Coefficient of intensity of impact of object on the environment	Object area, ha	Pond volume, m^3	Size of sanitary zone, m
Low (k_1=1)	<1	<10 thous.	<500
Medium (k_1=1.5)	1–10	10–250 thous.	500–1000
High (k_1=2)	>10	>250 thous.	>1000

Another important parameter that determines the degree of the negative effect of the object on the environment is the structural reliability. The reliability coefficient (k_2) is used for its assessment (Table 2).

Table 2

The reliability coefficient of waste storage facilities

Reliability coefficient of facility (k_2)	Wear coefficient of facility	Infilling of storage facility, %	Period of no-failure operation
1.5	>1	>100	<1 year
1	0.75–1	75–100	1–5 years
0.75	<0.75	<75	>5 years

The availability and efficiency of the environmental monitoring system can have a significant impact on the scale of the negative impact of the object, since the speed of decision-making in cases of accidental environmental pollution depends on it (Table 3).

Table 3

Coefficients of environmental monitoring efficiency (k_3)

Environmental monitoring efficiency (k_3)	Air quality measurement rate	Surface and ground water quality measurement rate	
1.0	daily	monthly	every 6 months
1.1	more rarely	more rarely	more rarely
1.25	Not available		

To calculate the indicator of the degree of potential environmental hazard of the object (l_0), the product of coefficients k_1, k_2, k_3 is determined. Depending on the size of the product, the indicator of degree l_0 is defined according to Table 4.

Table 4

The indicator of degree of potential environmental hazard of facility/object (l_0)

l_0	1	2	3
Product of coefficients k_1, k_2, k_3	<2	2–4	>4

Depending on the design of anti-filtration screens, the objects for accumulated IWW and sludge have the following coefficients of technological protection of ground water $k_{g.w}/l_{s.w}$ (Table 5). The indicator of the degree of natural protection of surface water ($l_{s.w}$) is given in Table 6.

Table 5

The coefficient of the negative impact of the object on ground water $k_{g.w}$

$k_{g.w}$/degree	Screen	Screen material	Thickness, m
1 (very high)	not available	–	–
0.75 (high)	Single-layer, only bottom	film	<0.3
0.5 (medium)	Single-layer, bottom and sides	soil, concrete	0.3–0.8
0 (almost no action)	Double-layer, bottom and sides	asphalt concrete, concrete+film, soil	>0.8

Table 6

The indicator of degree of natural protection of surface waters ($l_{s.w}$)

Total	3–4	5–6	7–8
$l_{s.w}$	0.5	1.0	1.5

The value of the degree of the potential negative effect of accumulated industrial waste on the environment is calculated by the formula:

$$C = D\ (\text{or } D_m) \cdot l_0 \cdot \left(l_a \cdot k_a + l_{g.w} \cdot k_{g.w} + l_{s.w} \cdot k_{s.w}\right), \quad (2)$$

where C – degree of potential negative effect of accumulated effluents and sludges; D – degree of their own danger; D_m – average degree of hazard of all types of effluents and sludges, is used in the case of joint storage of various types of waste materials; l_0 – degree of potential environmental hazard of the facility; l_a – degree of natural protection of the atmosphere; $l_{g.w}$ – degree of natural protection of ground water; $l_{s.w}$ – degree of natural protection of surface water; k_a, $k_{g.w}$, $k_{s.w}$ – coefficients of technological protection of the atmosphere, ground and surface water, respectively.

The degree of potential negative impact of accumulated materials on the environment is determined according to Table 7.

Table 7

The degree of potential negative impact of industrial waste water and sludge on the environment

Degree	low	medium	high
Values	<30	30–60	>60

By analogy with known projects and real objects, predictive estimation of the prevented and residual damage is made. The obtained data are compared with the costs for environmental measures, design, construction and maintenance of environmental protection facilities. The possibility of reclamation of redundant land is considered. The modernization of technologies for processing raw materials using low-waste methods is provided.

Quantitative methods for determining the prevented damage to the environment are based on estimating the masses of effluents, waste discharges and sludges as a result of the implementation of environmental measures. At the same time, reduction of degraded land areas and specific damage indicators are taken into account.

4. 2. Determination of priority directions and scale of growth in the use of secondary resources taking into account a set of environmental, economic and social factors

The important stage is development of measures to prevent, reduce, compensate and eliminate potential and real damage to the environment. The measures to compensate inflicted damage should correspond to the investment of financial and other resources.

Basic measures to prevent damage:

– development of low-waste technologies, reduction of hazard class of substances entering IWW and sludge ponds;

– development of technological schemes for diversion of waste water, its treatment and return to the main process;

– removal of agricultural objects from areas of influence of IWW ponds.

Measures to limit damage to the environment include:

– recovery of valuable components from IWW and sludges, use of neutral solid components as backfilling material and for construction of roads in the area of their owner;

– alloting areas for expansion of ponds taking into account the cost of alloted land, the volume of effluents and sludges, the relief, the wind rose.

Measures to eliminate damage are determined by the nature of alloted land, properties of accumulated materials and include:

– planning of relief with reclamation and use of territories for recreational purposes;

– conservation of toxic IWW and sludge with their diking, burial and use of generated areas for industrial and economic purposes;

– biological reclamation taking into account the future suitability of restored land (backfilling, gypsuming, laying of the fertile layer, sodding, etc.);

– burial of toxic sludge in special storages;

– utilization of IWW and liquid phase of stored sludge.

Fig. 4 shows dependencies for assessing the degree of damage to the environment in the area of location of IWW and sludge ponds.

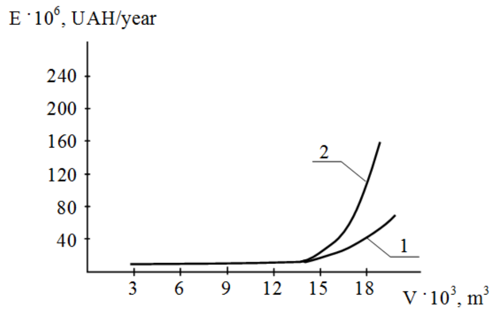

Fig. 4. Nomogram for determining damage to the environment from the impact of the pond of industrial waste water and sludge E depending on the volume of their storing V and hazard class: 1 — sludge of 3 hazard class; 2 — sludge of 1 hazard class

Social and economic prerequisites for solving the problems include:

– the awareness of the need for deep reform of the existing practice of nature management at all stages of production activities;

– the priority of environmental imperatives in the structural reorganization of the economy, the development of science and technology;

– the need to reform and develop the entire legal and economic system for control of environmental management.

At this stage, the definition of the main directions and scales of growth in the use of secondary resources taking into account a set of environmental, economic and social factors becomes of special importance [17].

Economic support should include the development of mechanisms for preferential taxation and crediting to business entities in the treatment of IWW and utilization of recoverable compounds of heavy metals. It is necessary to develop the provisions about methods for determining resource-valuable components, about the organizational and economic mechanism for managing subjects at regional and sectoral levels. It is very important to stimulate measures for their use by the State.

The concept of integral quality assessment of the environment is applicable for ranking of territories according to the level of technogenic load and degree of influence of this effect on its individual components. Analysis of the entire complex of ecological and economic functions shows that the existence of natural objects is much more valuable than the benefits derived from their one-sided industrial use. Even without taking into account environmental and social effects, which are not subject to economic evaluation, determination of economic damage from the environmental pollution at the stage of pre-design solutions helps to avoid many environmental and economic errors.

The reduced mass of the j-th pollutant in soil from the i-th source is determined by the formula:

$$M_{ri} = m_{ij} \cdot A_j \cdot S_{ij}, \quad (3)$$

where m_{ij} – annual mass of the j-th pollutant per area unit coming from the i-th source; A_j – ecological indicator of the relative danger of the j-th pollutant entering ~~in~~ soil; S_{ij} – area of the active zone of soil contamination by the j-th pollutant from the i-th source.

The magnitude of economic damage from the environmental pollution is not a normative indicator. Methods of its calculation in the CIS countries differ in the economic component. Therefore, it is difficult to compare the damage estimates obtained in different countries.

5. The results of studies of the negative effect of IWW and sludge ponds on the Dnepr river

The most common pollutants in water bodies of the Dnepr river are compounds of heavy metal (Mn, Cu, Zn, Fe ions, etc.), nitrogen compounds, phenols. According to hydrochemical observation~~s~~ data for the period 2011–2013, in general, the water quality in the rivers of the Dnepr basin has not changed significantly in most indicators.

The average annual concentrations of main pollutants exceeded the maximum permissible concentrations, and some were at the level of high pollution:

– Ammonium and petroleum products were within 1–4 MPC;

– Nitrogen nitrite – 1–12 MPC;

– Zn compounds – 1–5 MPC;

– Phenols – 1–6 MPC;

– Fe –1–7 MPC;

– Cr^{+6} – 1–13 MPC;

– Mn – 1–18 MPC;

– Cu compounds – 2–23 MPC.

The maximum content of Mn compounds in the range of 20–61 MPC was observed in the rivers of Dnepr, Sluch, Oster, Udai, Psel, Sula, Khorol, Vorskla, Volchya, Ingulets and Dneprovsky reservoir. Significant amounts of Cu compounds, within the scope of 31–59 MPC, were found in the rivers of Dnepr, Ustye, Sluch, Desna, Sula, Kremenchug and Dneprodzerzhynsk reservoirs. Concentrations of Zn compounds, within 10–16 MPC, were determined in the water of Kiev, Kremenchug and Dneprodzerzhynsk reservoirs. In the rivers of Samara, Volchya, Solenaya, there are always cases of high pollution by sulphates.

The important direction in the study of processes of reducing the negative impact of IWW ponds is an investigation of migration paths of filtrates with soluble compounds of heavy metals in soil.

The main types of effect of IWW and sludge ponds on the environment are release of toxic components of raw materials, effluents, wastes into the atmosphere, water basin, ground waters and earth surface. Fig. 5 shows a schematic diagram of entry of heavy metal ions into surface and ground waters and soil, and their content in soil near the IWW pond.

The main sources of impact of enterprises on water basin are discharges of untreated and conditionally treated industrial waste water. Also, the negative effect is exerted by filtrate and surface flows from IWW and sludge~~s~~ ponds. The deposition of the solid phase of organized and unorganized dust-gas emissions into surface water bodies can be significant.

Indicators of environmental pollution are chemical compounds that correspond to the composition of raw materials, discharges of IWW and sludges taking into account the background of location of the enterprise-pollutant. Damage objects are water bodies within the dispersion of pollution indicators, landscapes. In general, the potential, preventable, compensable, liquidated and residual types of damage to the environment are determined. About 50 % of ponds are concentrated in the southern part of the basin. These are filterable ponds, from which solutions of soluble salts enter surface and ground waters. More than 40 % of the ponds of the basin are very dangerous (Fig. 1–3, 5–8).

A structural scheme for minimizing the damage to the environment from the impact of sludge pond is shown in Fig. 9.

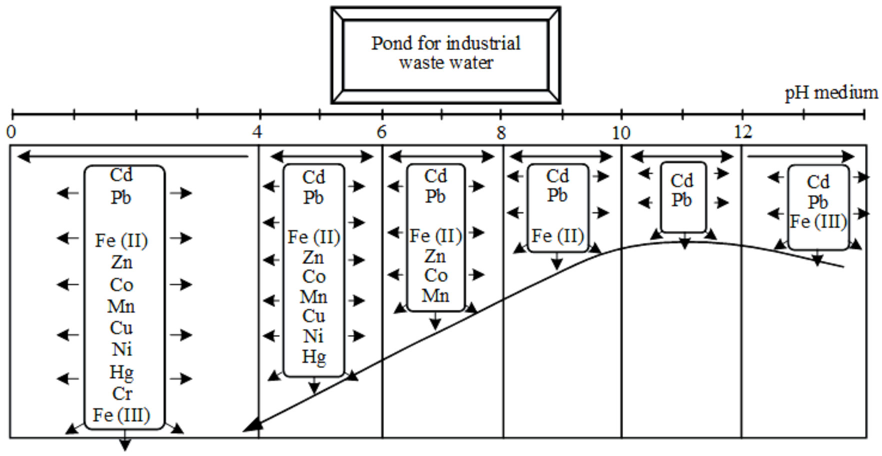

Fig. 5. The scheme of entry of heavy metal ions from industrial waste water into surface and ground waters, volume of industrial waste water and sludge pond

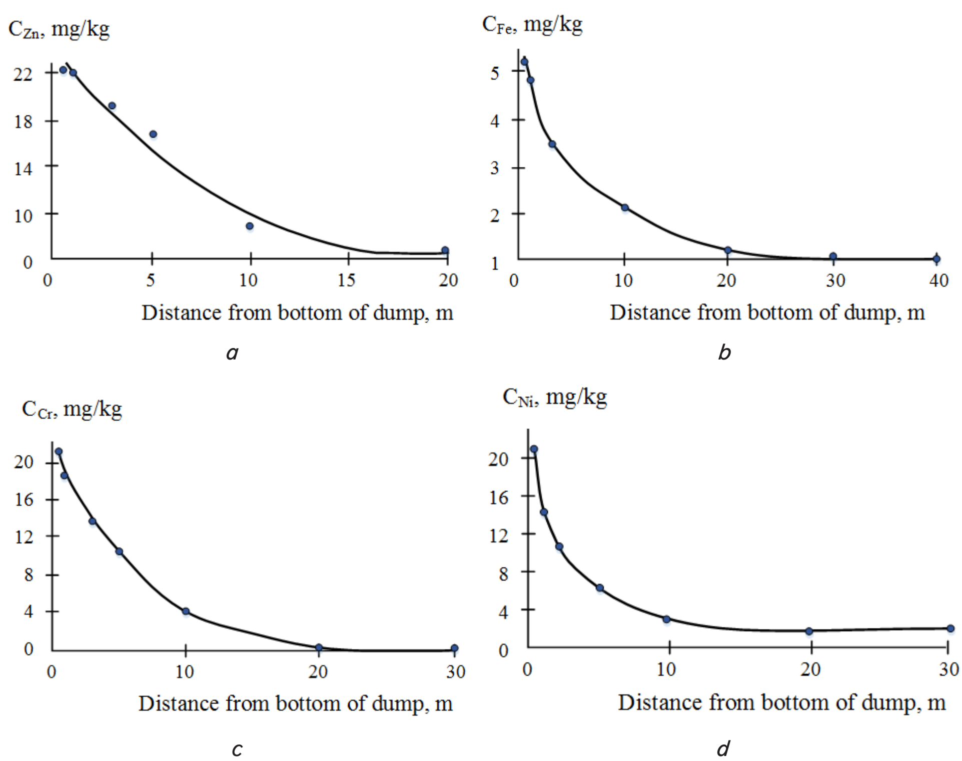

Fig. 6. The content of heavy metals in soil near industrial waste water and sludge ponds: *a* – zinc concentration C_{Zn}; *b* – iron concentration C_{Fe}; *c* – chromium concentration C_{Cr}; *d* – nickel concentration C_{Ni}

Fig. 7. Discharge of untreated waste water from "Zaporizhstal metallurgical plant" (Ukraine) into the industrial waste water and sludge pond ("balka Kapustyanka"): *a* – discharge of waste water from rolling-mill processes; *b* – discharge of waste water from pickling and galvanic processes

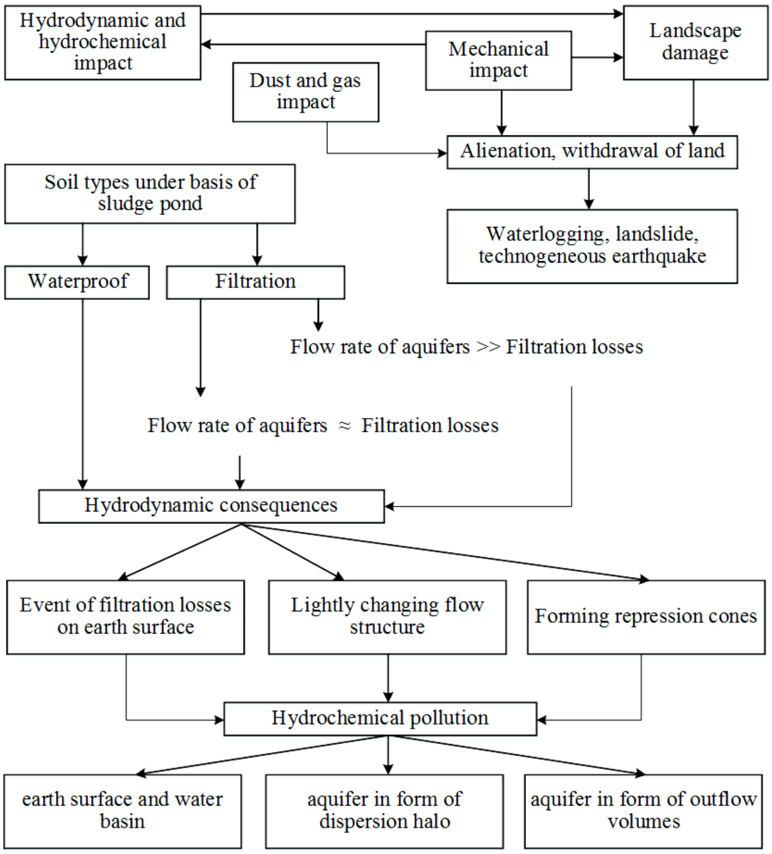

Fig. 8. Factors of effect of industrial waste water pond on the water basin

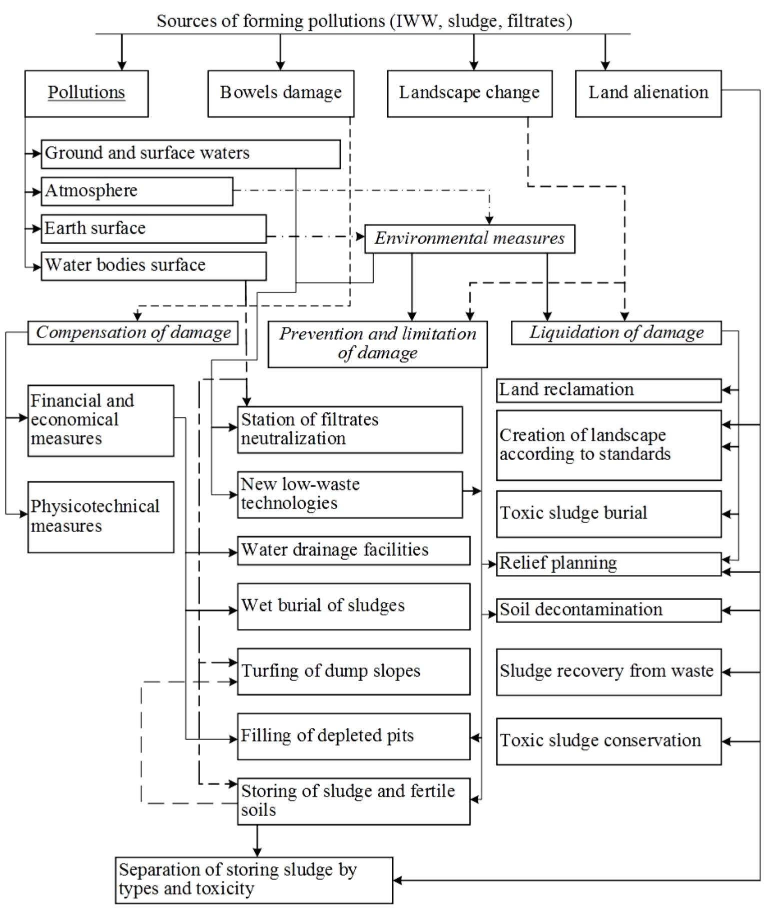

Fig. 9. The structural scheme of minimizing damage to the environment from the impact of industrial waste water and sludge ponds

The problems of preventing damage to the environment in the areas of location of ponds of untreated IWW and sludges from industrial enterprises have a dual nature. From the one hand, these flows contain heavy metals, and from the other hand, they cause serious damage to all areas of the environment.

The feasibility of investing in the recovery of valuable components from discharged industrial waste water and sludge is characterized by a large economic effect and a short payback period of created facilities.

6. Discussion of the results of the study of the state of the water basin of the Dnepr river in the area of location of "Zaporizhstal" metallurgical plant and its water collecting facility "b. Kapustyanka"

To prevent pollution of the water basin by waste water and sludges from the sludge pond of "Zaporizhstal" metallurgical plant, it is advisable to carry out a set of research, design and survey works to study the properties of accumulated scale deposits in the areas of its discharges in the sludge pond. This allows creating a production complex for scale utilization. According to technology developed by SE "UkrRTC "Energostal", briquettes (pellets) enriched with iron can be used in the main processes of the plant.

The investigated pond with capacity of 10.5 mln. m³ was designed by "Vodokanalproekt" (Kharkiv, Ukraine). The discharge of IWW and sludge into it is 1.1 mln. tons/year, service life is 25 years, the area of the sludge pond is 135 ha, the sludge pond has been operated since 1958. The pond is designed for discharging IWW and sludge:

– from "Zaporizhstal" – sludge from the wet gas cleaning of the sinter plant, blast furnaces, open-hearth furnaces, continuous casting machines, flows of the head and power plant, watered scale of rolling-mill shops, molds shop, waste emulsions, etc.;

– from by-product coke plant – coal cleaning sludge, part of chemically contaminated IWW;

– from "Aluminum Plant" – sludge from the wet gas cleaning of the head and power plant, operating on solid fuel, and sludge of alumina processes;

– from "Dneprospetsstal" plant – watered rolling scale, neutralized and acid IWW, wet gas cleaning sludge;

– from "Hardware plant" – neutralized and acid IWW;

– from "Kremniypolimer" plant – sludge of chemical processes.

In 1979, recirculating cycle for IWW from the hot plate rolling mill (NTLS-1680) was commissioned. Heretofore, the flows, contaminated with scale and oils, from primary settling tanks were discharged into the sludge pond. Taking into account that, in present time, the recirculating cycle system collects an average of 12.000 tons/year of scale, in the period from 1958 to 1979 the scale, contained in IWW, was accumulated in the bed of "balka Kapustyanka" and during 20 years its mass was more than 252 thous. tons.

The layout of horizontal settling tanks and the composition of the equipment of the water supply shop at "Zaporizhstal" is shown in Fig. 10. Schematic diagram of recovery of iron-containing bottom deposits of scale from the water collecting facility "b. Kapustyanka" is provided in Fig. 11. The specialists of the plant modernized gas cleaning equipment of the sinter plant and hydrotechnical facilities of recirculating water supply cycle for wet gas cleaning of blast furnaces. This allows decreasing significantly discharge of IWW into the water collecting facility "b. Kapustyanka".

SE "UkrRTC "Energostal" developed a new low-waste economically-efficient technology for wet oily scale recovery. Obtained iron-enriched briquettes or pellets are suitable for use in the main processes of the plant. Representative scale samples of "Zaporizhstal" were used as raw material.

As a result, the reduced volume of waste water of the plant comes into the water collecting facility. 150 m^3/hour of industrial waste water is discharged from gas cleaning of the sinter plant, 400 m^3/hour with a concentration of suspensions up to 200 mg/dm^3 and mineralization up to 2500 mg/dm^3 – from the recirculating water supply cycle for gas cleaning of blast furnaces. In some cases, in the event of failures during the IWW supply from gas cleaning to the recirculating cycle, the emergency discharges in the volume up to 600 m^3/hour with a concentration of pollution up to 5 g/dm^3 can occur.

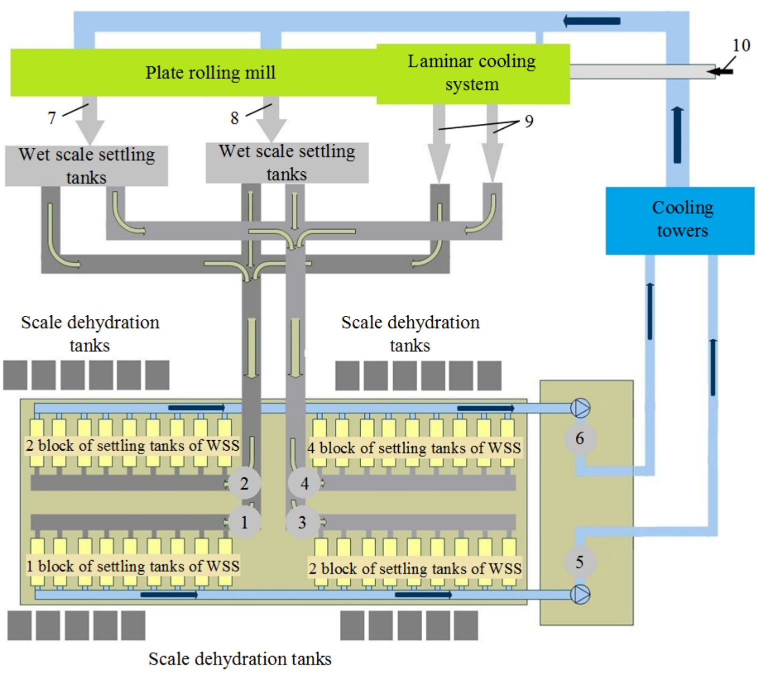

Fig. 10. Layout of horizontal settling tanks and the composition of the equipment for the water supply shop at "Zaporizhstal": water supply shop (WSS); 1, 2 – sludge pipelines No. 2; 3, 4 – sludge pipeline No. 1; 5, 6 – clarified water pumps; 7 – scale-containing industrial waste water from cooling of methodical furnaces and roughing stands group; 8 – scale-containing industrial waste water of cooling of finishing stands group; 9 – scale-containing industrial waste water of the laminar cooling system; 10 – supply of industrial water from the Dnepr river

Fig. 11. Working of sludge deposits of the water collecting facility in "balka Kapustyanka" at "Zaporizhstal" (Ukraine): 1 – site of "Zaporizhstal" plant; 2 – recirculating cycle of scale-containing industrial waste water; 3 – slurry pipeline L=1.5 km, D=600 mm; 4 – dredger

7. Conclusions

1. Based on the results of conducted investigations of water quality in water bodies of the basin of the Dnepr river, the most common pollutants are compounds of heavy metals (Mn, Cu, Zn, Fe ions, etc.), nitrogen compounds, phenols. According to hydrochemical observations, during the period 2011–2013, in general, the water quality in rivers of the Dnepr basin has not changed significantly in most of the indicators: average annual concentrations of main pollutants exceed MPC, and some are at the level of high pollution.

2. The average annual concentrations of pollutants in the water of the Dnepr river and its main tributaries were defined. The maximum content of Mn compounds, in the range of 20–61 MPC, was observed in the rivers of Dnepr, Sluch, Oster, Udai, Psel, Sula, Khorol, Vorskla, Volchya, Ingulets and Dneprovsky reservoir. Significant amounts of Cu compounds, in the range of 31–59 MPC, were found in the rivers of Dnepr, Ustye, Sluch, Desna, Sula, Kremenchug and Dneprodzerzhynsk reservoirs. Concentrations of Zn compounds, in the range of 10–16 MPC, were determined in the water of Kiev, Kremenchug and Dneprodzerzhynsk reservoirs.

3. To reduce the negative impact of waste water and sludges from the main processes of "Zaporizhstal" on the water basin of the Dnepr river, gas cleaning equipment of the sinter plant and hydrotechnical facilities of recirculating water supply cycle for wet gas cleaning of blast furnaces was modernized. This allows decreasing significantly discharge of IWW into the water collecting facility "balka Kapustyanka". Further, it is advisable to carry out a set of research, design and survey works to study the properties and actual volumes of accumulated scale deposits in the areas of its discharges in a sludge pond. This allows creating a production complex for scale utilization. According to the technology developed by SE "UkrRTC "Energostal", briquettes (pellets) enriched with iron can be used in the main processes of the plant.

The results of conducted investigations can be useful for forecasting consequences of the impact of discharged IWW ponds, tailing dumps and dumps of large-tonnage waste on the environment.

References

1. Farkas, A. Assessment of the environmental significance of heavy metal pollution in surficial sediments of the River Po [Text] / A. Farkas, C. Erratico, L. Vigano // Chemosphere. – 2007. – Vol. 68, Issue 4. – P. 761–768. doi: 10.1016/j.chemosphere.2006.12.099
2. Saleem, M. Dissolved Concentrations, Sources, and Risk Evaluation of Selected Metals in Surface Water from Mangla Lake, Pakistan [Text] / M. Saleem, J. Iqbal, M. H. Shah // The Scientific World Journal. – 2014. – Vol. 2014. – P. 1–12. doi: 10.1155/2014/948396
3. Kumar, M. A study of trace element contamination using multivariate statistical techniques and health risk assessment in groundwater of Chhaprola Industrial Area, Gautam Buddha Nagar, Uttar Pradesh, India [Text] / M. Kumar, A. Ramanathan, R. Tripathi, S. Farswan, D. Kumar, P. Bhattacharya // Chemosphere. – 2017. – Vol. 166. – P. 135–145. doi: 10.1016/j.chemosphere.2016.09.086
4. Burgassa, M. J. Navigating uncertainty in environmental composite indicators [Text] / M. J. Burgassa, B. S. Halperna, E. Nicholsone, E. J. Milner-Gullandb // Ecological Indicators. – 2017. – Vol. 75. – P. 268–278. doi: 10.1016/j.ecolind.2016.12.034
5. Ebrahimi, M. Temporal performance assessment of wastewater treatment plants by using multivariate statistical analysis [Text] / M. Ebrahimi, E. L. Gerberb, T. D. Rockawaya // Journal of Environmental Management. – 2017. – Vol. 193. – P. 234–246. doi: 10.1016/j.jenvman.2017.02.027
6. Malik, O. A. A global indicator of wastewater treatment to inform the Sustainable Development Goals (SDGs) [Text] / O. A. Malik, A. Hsu, L. A. Johnson, A. de Sherbinin // Environmental Science & Policy. – 2015. – Vol. 48. – P. 172–185. doi: 10.1016/j.envsci.2015.01.005
7. Ogunkunle, C. O. Assessment of metallic pollution status of surface water and aquatic macrophytes of earthen dams in Ilorin, north-central of Nigeria as indicators of environmental health [Text] / C. O. Ogunkunle, K. Mustapha, S. Oyedeji, P. O. Fatoba // Journal of King Saud University – Science. – 2016. – Vol. 28, Issue 4. – P. 324–331. doi: 10.1016/j.jksus.2015.11.005
8. Islam, S. Total and dissolved metals in the industrial wastewater: A case study from Dhaka Metropolitan, Bangladesh [Text] / S. Islam, S. Islam, Habibullah-AL-mamun, S. A. Islam, D. W. Eaton // Environmental Nanotechnology, Monitoring & Management. – 2016. – Vol. 5. – P. 74–80. doi: 10.1016/j.enmm.2016.04.001
9. Liao, J. Heavy metals in river surface sediments affected with multiple pollution sources, South China: Distribution, enrichment and source apportionment [Text] / J. Liao, J. Chen, X. Ru, J. Chen, H. Wu, C. Wei // Journal of Geochemical Exploration. – 2017. – Vol. 176. – P. 9–19. doi: 10.1016/j.gexplo.2016.08.013
10. Kasimov, A. M. Osnovnye meropriyatiya po likvidacii ushcherba okruzhayushchei prirodnoi srede v raione razmeshcheniya nakopitelei othodov metallurgicheskih zavodov [Text] / A. M. Kasimov // Chernaya metallurgiya. – 2011. – Issue 12 (1344). – P. 70–72.
11. Kasimov, A. M. Migraciya ionov tyazhelyh i redkih metallov v pochvah vokrug zoloshlakovyh otvalov ryada ugol'nyh TEHS Ukrainy [Text] / A. M. Kasimov // Mater. 1X Mezinarodni vedecko-praktika Konference «Vedecky Promysl Evropskeho kontinentu-2013. 27.11.2013-05.12/2013». – Praha, 2013. – P. 75–81.
12. Lomsadze, Z. The ecological problems of rivers of Georgia (the Caspian Sea basin) [Text] / Z. Lomsadze, K. Makharadze, R. Pirtskhalava // Annals of Agrarian Science. – 2016. – Vol. 14, Issue 3. – P. 237–242. doi: 10.1016/j.aasci.2016.08.009
13. Fu, F. Removal of heavy metal ions from wastewaters: A review [Text] / F. Fu, Q. Wang // Journal of Environmental Management. – 2011. – Vol. 92, Issue 3. – P. 407–418. doi: 10.1016/j.jenvman.2010.11.011
14. Angelakis, A. N. Water recycling and reuse in EUREAU countries: Trends and challenges [Text] / A. N. Angelakis, B. Durham // Desalination. – 2008. – Vol. 218, Issues 1-3. – P. 3–12. doi: 10.1016/j.desal.2006.07.015
15. Klemes, J. J. Industrial water recycle/reuse [Text] / J. J. Klemes // Current Opinion in Chemical Engineering. – 2012. – Vol. 1, Issue 3. – P. 238–245. doi: 10.1016/j.coche.2012.03.010
16. Bratina, B. From municipal/industrial wastewater sludge and FOG to fertilizer: A proposal for economic sustainable sludge management [Text] / B. Bratina, A. Sorgo, J. Kramberger, U. Ajdnik, L. F. Zemljic, J. Ekart, R. Safaric // Journal of Environmental Management. – 2016. – Vol. 183. – P. 1009–1025. doi: 10.1016/j.jenvman.2016.09.063
17. Kasimov, A. M. Ekologicheskie i ehkonomicheskie instrumenty sokrashcheniya ushcherba okruzhayushchei prirodnoi srede so storony nakopitelei promyshlennyh othodov [Text] / A. M. Kasimov, I. V. Gurenko, I. N. Macevitaya // Ekologiya i promyshlennost'. – 2013. – Issue 1. – P. 79–83.