

Features of protection of soils from erosive degradation and pollution in industrial regions

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The purpose. To find complex solution of a problem of water erosion and pollution of soils, caused by industrial wastes. **Methods.** Analysis of maps and charts, monitoring of erosion processes on waste dumps of coal mines, field observation and measurement, probe of water permeability of rock refuse by method of tubes, physical simulation of blowing erosion of rock using laboratory aerodynamic device. Analytical-synthetic methods in view of fund, statistical materials and normative-legal baseline. **Results.** In natural conditions it is determined that from waste dumps of Public joint-stock company «Lisichanskugol» in Lugansk oblast at absence of protective plant cover as a result of water erosion about 3500 t/hectare of rock during their existence or up to their afforestation are carried out. Potential removal of rock at blowing erosion exceeds 150 t/hectare. It is shown that afforestation improves water permeability of rock in 5 times. That is the reliable factor of termination of water-erosion process and prevention of removal of pollutants in visual environment. It is proved that there is a legal opportunity and ecological expediency of including terraces in circuits of local ecological nets with their subsequent afforestation. Necessity of use in eco-net as ecological alleyways, besides fluvial net, of primary hydrographic network in the form of hollows is justified. The generality of use of terraces in local eco-net and implementation of contour-meliorative architecture of agro-landscapes on separate operations and as the complex factor of protection of soils from erosion and pollution is shown. **Conclusions.** On an instance of Lugansk oblast it is shown that inclusion of terraces of coal mines and mining factories in local ecological nets with the status of rebuilt terrains will stimulate their afforestation, promoting thorough lowering of removal from them of pollutants. For complex solution of problem of erosive degradation of soils and spread of pollutants in agro-landscapes it is necessary to implement contour-meliorative architecture.

Key words: *degradation, pollution, erosion, waste dump, protection of soils, ecological net.*

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Ensuring of the population of Ukraine with sufficient quantity of quality food is the most important task of the country's agro-industrial complex, but its solution find difficulty in the reduction of the area of fertile lands due to soil erosion and pollution of soil with industrial waste.

According to [1], from 1961 to 2015, the area of eroded arable land in Ukraine increased from 8 to 10.6 million hectares and reached 32% of the total area of arable land, and arable land exposed to wind erosion reached 6 million hectares. The annual growth of the area of eroded lands exceeds 80 thousand hectares. Total soil losses in Ukraine from water and wind erosion amount to 450-600 million tons, including 11-20 million tons of humus, every year [2]. The result of these losses is the decline in yields for weak-, medium- and high-eroded soils, respectively, by 15-20%, 30-40% and 50-60% respectively, and in general, the loss of crop production exceeds 9-12 million tons of grain units [3].

The area of arable land, contaminated with heavy metals (VM), in Ukraine is 8% [4]. Most of the contaminated lands are the result of mining enterprises, which in the Ukraine are more than 2 thousand, of a large mass of waste and their storage in high dumps, regardless of the type and method of mining of minerals.

Only within Lugansk and Donetsk regions there are more than 1200 waste dumps of coal mines – of terricones. Their total volume and occupied area exceed respectively 1 billion cubic meters and 5500 hectares. Due to the high steepness of the slopes of dumps - up to 40°, their height (up to 100 m and up) and due to poor protection of dumps by vegetation, catastrophic erosion processes with extraordinary intensity occur on them [5], many of them burn. There are waste dumps in the east of the Dnipro region, in the Lviv-Volyn Carboniferous Basin. The ecological danger of the inflow of the waste rock on the adjoining territory is determined by the high content of heavy metals (HM) in it, especially Ni, Pb and Cu, which exceeds the top

permissible concentration (TPC) of the mobile form to 2.5 - 7 times. The high content of HM is observed in the soil around the dumps and in the agricultural products collected from it [5].

There are many mining-metallurgical plants in Ukraine, they located mainly in the Krivoy Rog-Kremenchug iron ore zone, the Nikopol Manganese-ore basin. There are 1735 non-metallic deposits located in 22 regions of Ukraine, with which 48-50 thousand hectares of disturbed lands are connected. The source of deflationary contamination of the soil are also sludge and tailings of the mining and dressing combines.

The purpose of the research is to find ways of the integrated solution of the problem of soil erosion and pollution associated with industrial waste.

Materials and methods of research. As the objects of research were waste rock dumps of coal mines and surrounding agrolandscapes of the Lugansk region. The basic researches were carried out on non-operating dumps of mines named after P. Voykov and D. Melnikov of PJSC "Lisichanskugol". The method of field inspection of dumps and landscapes, analysis of cartographic materials and measurements of terrain indicators were used.

To measure the effects of water erosion on the dumps, the width and depth of the rills were measured. The intensity of the deflation of the waste rock was investigated by the method of physical modeling using the developed aerodynamic plant [6]. The waste rock permeability to water examined by the method of tubes.

Research results. According to the obtained results, one can state the catastrophic nature of the water and wind erosion of the dump surface. Thus, the deflation modeling showed that the potential annual flying out of rock from wind exceeds 150 tons from 1 hectare of their surface, and the long-term washing away of the waste rock exceeded 3400 tons per hectare (Table 1). With uniform deposition of rock around the dump within the sanitary protection zone (SPZ) 500 m wide, each hectare of dump surface forms pollution with a mass of more than 30 tons of rock per 1 hectare of soil surface, but the rock is postponed extremely unevenly, and this causes an extremely high pollution in the immediate proximity to the dump and in the hollows where migration of pollutants occurs.

1.Characteristics of rock washing from the slopes of dumps

The mines name	The number of rills	The area of the cross section of the rills, m ²		Long-term washing out of waste rock from the the dump, t / ha
		average	total	
After P. Voykov	7	0,245	1,714	2570
After D. Melnikov	5	0,89	4,47	3450

The fundamental difference between the data of the dumps is that on the unafforested areas of the first of them erosion process continues today, and on the second, under the influence of self-graying woody vegetation, erosion process has stopped, as evidenced by the accumulation of forest litter at the bottom of the rills. For detection of the mechanism of such influence of vegetation the permeability of the rock to water was investigated. The water was poured into steel tubes of 100 mm in length, clogged to a depth of 70 mm at the bottom of the rills up to 1 m deep with a thick layer of forest litter and outside it.

As the measurements shown (Table 2), even after an hour of water supply, the permeability of the rock at the bottom of the rills was 3.8 times higher, and on average per hour it was 5 times higher than the permeability of the rock outside the rills.

2. Indicators of dynamics of water absorption into the waste dump rock

No. point	Location of the site	Time (min)					Average rate of absorption, mm / min	
		1	10	20	30	60	in 30 min	in 60 min
1	Bottom of the rills	45,3	12,9	8,9	7,1	4,9	16,0	11,0
2	Outdoor rills	6,4	2,6	2	1,7	1,3	2,9	2,2

It is this known influence of woody vegetation on soils that led to the complete absorption of the surface runoff and stops the rills development on the dump of the mine named after D. Melnikov, as well as many others, artificially or naturally afforested. But the cessation of erosion occurred only after the seeds of the ash-leaved maple were brought into the rills, and the rills were overgrown.

Artificial afforestation of the dump after the end of its formation would prevent such a huge excavation of the waste rock on the adjacent land. The anti-deflation effect of vegetation appears earlier - when the trees reach a height of 1-2 m, and their rows, located in the rills after 2-3 m, begin to work as a system of anti-deflation forest belts.

Thus, the most effective measure to prevent wind and water erosion on dumps, and therefore soil contamination, is the afforestation of their surface.

The average annual soil losses in the eroded territories of Ukraine are estimated at 15-20 t / ha [2], and the maximum registered in the Luhansk region reaches 280 and 95 t / ha respectively, with heavy shower and runoff of water from melted snow [7], due to deflation - 110-120 t / ha [8]. That is, the problem of erosion in the Ukraine requires an urgent solution.

The generally accepted method of protection of soil against erosion is the introduction of a soil protection contour-reclamation system of farming (CRF) [9, 10], which was proposed at the Institute of Farming of NAAS. It is ensured, firstly, by the introduction of the contouring-reclamation organization of the territory; and secondly, by differentiated use of arable lands depending on the erosivity and steepness of the slopes; and third, by the creation of a field hydrographic network [2].

The first step towards the creation of this network is the artificial grassing of the natural primary hydrographic network, that is, the hollows [3, 9]. If necessary, this measure in accordance with [5] is reinforced by runoff-control banks and forest shelter-belts.

But not all the hollows can and should be transformed into grassed watercourses. Very short distance between them complicates the working conditions of machine operators. To decide the question about expediency of the grassing of either hollows, one must know the runoff load on them, the danger and degree of washing out, the parameters of their cross-section and the patterns of hollows placement in the landscape.

The hollows is inalienable element of the microrelief of the slope lands. As shown in the monograph [7], their origins appear already at a distance of 100-200 m from the watershed line, from slope steepness of 0,5-1°. By analyzing of the cartographic materials of the Lugansk region, in the monograph it was proved that the parameters of the hollows location and of their transverse section at a certain distance from the watershed line have a connection with this distance, the slope steepness, its transverse shape and the radius of curvature of the contours (R). These links are illustrated for slopes a straight transverse shape (R above 1000 m) in Table. 3

3. The most probable parameters of the hollows network within different ecological-technological groups (ETG) of lands [7]

Number of ETG, slope steepness	Length of the slope, m	<i>Parameters of the hollows network, m</i>				Part of the hollows catchment from the slope area, %
		depth of the hollows, m	hollows slope steepness	distance between the hollows thalwegs, m	the width of the hollows, m	
I (1-3°)	100-1500	0,30-0,75	0,005-0,012	150-260	110-185	72
II (3-5°)	100-1500	0,30-1,00	0,010-0,018	110-180	75-130	70
III (5-7°)	500-1000	0,70-1,20	0,014-0,020	90-130	65-90	70

As the study [7] has shown, due to the concentration of surface runoff along the tales of the hollows, their bottom is the most vulnerable element of the slope lands, where linear erosion often occurs - more often than the small-rill erosion of the catchment area of the hollows. It occurs when there is less precipitation or a layer of runoff, it has the appearance of shallow gullies width of 8 m and causes soil loss to 30-50 m³ per 100

m of the length of hollows. When machining the soil, the hollows are filled with soil, shifted from the slopes of the hollow. For the temporary existence of its manifestation, erosion of the hollows bottom in foreign sources is called as *ehphemeral gully erosion*. Soil losses from the bottom of the hollows are also offset by the soil that is washed away from their slopes, as evidenced by a more powerful soil profile, blocked by the deluvial deposits of less humus soil, identical to the ground of the slopes. As noted in [7], the deluvium is in the hollows with a depth of more than 0.9 m, its height increases with the depth of hollow and decreases with an increase in the average slope of the thalweg steepness.

Thus, erosion degradation of soils on sloping lands occurs as a result of wasing away of soil from the catchments of the hollows, first being carried out at their bottom, and then along their thalwegs beyond the boundaries of the field. As figuratively stated in [7], hollows are the channels, on which the soil fertility is lost from the fields. Therefore, the return of the hollows to the baseline by grassing of their bottom can be considered as the most natural means for preventing soil degradation.

Of course, this tool is not sufficient, since the grass planting on the bottom of the hollows does not affect the erosion of the hollows catchment. But, as evidenced by the study [8], the soil washed away from it almost completely deposited in the grass cover, and the transfer of soil outside the field decreases to 25-30 times. The sowed by grass watercourses are durable. Established in the former state farm "Udarnik" in 1978, according to local residents, they still exist. The most effective is the measure of a more complete return of the land to the original state - the removal of them from cultivation within the limits of the third ETG (slopes above 5° with medium- and high-eroded soils) according to [2].

The economic problems of recent years weakened the society's efforts to solve the problem of soil erosion and biological recovery of waste dumps. Due to the shortage of internal motivations in the state to solution of these problems, we can find them, in our opinion, in its external commitments, namely in the development of the National Ecological Network.

For establishing EECONET, European countries create the own National ecological networks. The official formation of the ecological network in Ukraine began after the adoption of the Law of Ukraine No. 1989 III of 21.09.2000 "On Approval of the National program for the formation of the national ecological network of Ukraine for 2000-2015".

The need to build eco-networks in Ukraine is currently being considered in the light of the signing of the Association Agreement with the EU and the gradual approximation of environmental legislation to the relevant EU directives. The draft law submitted to the Parliament by the Cabinet of Ministers (No. 8328 of April 26, 2018) "On the main principles (strategy) of the state environmental policy of Ukraine for the period up to 2030" indicates the need to "... increase the area of land in the ecological network, which is strategic the task of achieving the ecological balance of the territory of Ukraine".

The main objective of the "National program for the formation of the national ecological network of Ukraine for 2000-2015" was "to increase the area of the country's land with natural landscapes ..., the formation of their territorially unified system, constructed in accordance with ensuring the natural ways of migration and the spread of plant and animal species, which would ensure the conservation of natural ecosystems, species of flora and fauna and their populations."

It is important to note that along with the tasks in the field of the formation of the national econet, an important place in the "Program ..." is given to the tasks for the protection and reproduction of land resources. For this purpose, "optimization of agricultural land areas and reduction of the degree of their cultivation; ..; introduction of a soil protection system of agriculture with the contouring-reclamation organization of the territory; conservation of agricultural lands with very washed and deflated soils on steep slopes of more than 5 - 7 degrees " are intended.

The introduction of soil protection issues into the program for the formation of the national ecological network is not accidental, since the two above mentioned spheres are largely solved in the same way and, above all, by increasing the share of areas with natural vegetation cover - forest and meadow vegetation, which preserve erosion-hazardous areas from further degradation and is, at the same time, an environment of plant and animal species. We will show, how the solution of the specified tasks "Programs ..." and the

problems of soil pollution prevention can be achieved by including of industrial waste dumps in the ecological network.

As it is known, ecological corridors of different hierarchical levels are created to ensure the possibility of migration and resettlement of animals in existing and new areas. The largest are the corridors of the National Ecological Network [11]. The main species is the valleys of the middle and large rivers, therefore they do not form a sufficiently dense network of corridors, their main task is to combine the landscapes of the regions of Ukraine between themselves and with the ecological networks of other countries.

According to the legislation, consolidation of the network of corridors and key territories of the National Ecological Network is carried out by designing regional and local (district and city) ecological networks using "Methodological recommendations ...", approved in 2009 [12].

An example of implementation of the recommendations is the regional ecological network of the Lugansk region, developed by the Scientific Research Institute of Applied Ecology under the East-Ukrainian National University named after V. Dahl according to the Regional target program for the development of the econet of the Luhansk region for 2010-2020 (decision of the Regional Council dated December 3, 2009 No. 32/19). The scheme includes the meridian ecological corridors, located along the valleys of the rivers; interstate key territories; nature reserves; latitudinal ecocorridors: Troitsko-Milovskii, Pokrovsko-Bilovodskii, Swativsko-Gorodishchanskii, Siverskodonetskii, Severo-Donetskii and Yuzhno-Donetskii [13].

The atlas [14] presents the schemes of local ecological networks, developed by its authors for almost all administrative regions of the Luhansk region. Undoubtedly, they will be important for the implementation of the regional econet in the Luhansk region, but their analysis shows a significant defragmentation of both key territories and corridors of many of the local eco-networks. And this is a consequence of the problem of insufficient number of sites with natural wood and herbaceous vegetation in densely populated industrial areas. And the available forest areas, due to the close location of settlements, experience a great recreational load and therefore are not a reliable storehouse for animals and birds. In areas with meadow vegetation, there are no conditions for preserving its valuable species due to population gathering and grazing of cattle.

That is why it is expedient to use as an additional space for local eco-networks the surface of waste dumps with formed vegetation, proposed by scientists [15-17] for Kryvbas and Donbass, which is in full agreement with the "Recommendations..." [12], according to which for the open-cast mine and waste dumps in the eco-network has been granted the status of *regenerated territories*. Including of insufficiently afforested dumps in the ecological network will facilitate the work on their afforestation, and this will be a reliable factor in reducing the release of toxic substances from them. Theoretically, in the first years of life of wooden plantations, the deflation of the surface of dumps is substantially weaker, and during the growth of plantations, as was shown above, water erosion will start to decay. First, to reduce the removal of the rock it can use the trenches and banks described in the monograph [5].

The location of mines and separate waste dumps in Lugansk and Donetsk regions is shown in Fig. 1. As we can see, they cover a large territory and are a factor that, in addition to high urbanization, increases the defragmentation of natural lands; therefore, it is important to turn this disadvantage into a dignity by finding means for linking of dumps with each other and with regional ecocorridors.

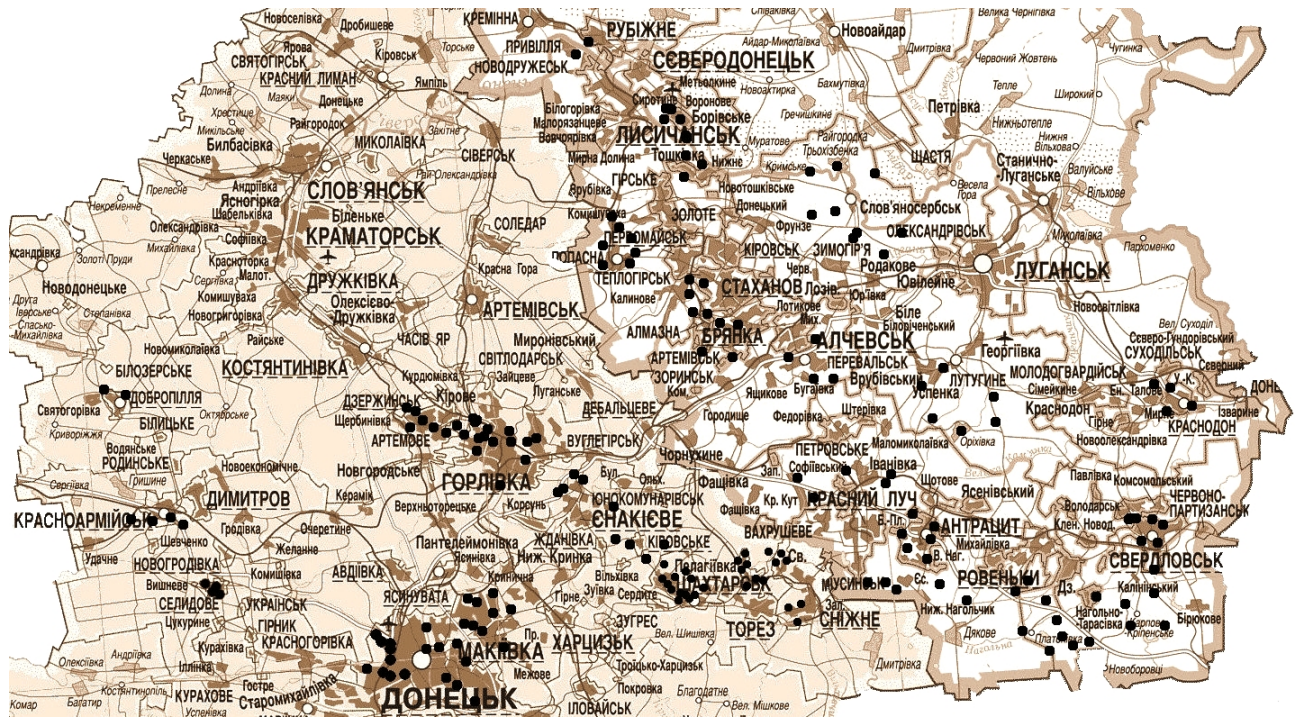


Fig. 1. Location of coal mines and some waste dumps on the territory of Donetsk and Luhansk regions

As local ecological corridors in [12, 17] it is proposed to use a river network. But in our view, as with dumps and as without them, only rivers is not enough in the local econet. The wide range of questions connected with the peculiarity of functioning of river networks as natural ecological corridors, has been considered in the works [18-20]. Thus, in the Lugansk region, the density of the river network is 0.12 km / km² [5], that is, the average distance of rivers each from other is 8.33 km. Therefore, in Donbass, where many dumps are located within settlements, overcoming this obstacle between adjoining rivers for wildlife is an impossible task.

In fact, this problem is solved by nature, due to the existence of a network of waterless valley that always lead to river valleys. In Lugansk region, its density varies from 0.75 to 1.2 km / km², that is, the mutual distance of adjacent waterless valley is 1.33 - 0.83 km, which is 6.3-10 times smaller than the rivers. The waterless valley are usually covered with meadow and woody perennial vegetation, which can serve as a shelter for migrating animals. However, the waterless valley are not always located close enough to the dumps. Therefore, as an additional intermediate element of the hierarchical system of ecocorridors, we propose the use of the primary hydrographic network – of hollows. As shown in Table. 1, the hollows in the first ETG are mutually distant on average by 200 m, while in the second and third they are even smaller, that is, they are always near or below the dumps.

All the hollows on arable land near the dumps should be removed from the arable land and grassed. This will ensure the connection of phytocoenoses, which are formed later in the dumps, with the river network, will stop the migration of pollutants along the hollows, the linear erosion of their bottom and carrying out of soil, which is washed away from catchments of hollows, beyond the boundaries of the field. But the main role in preventing soil contamination belongs to the dumps afforestation. As an additional measure to increase the reliability of soil protection, it is expedient to use other elements of CMF, and above all a system of forest runoff-control and shelter-belts, which, along with the soil protection effect, will increase the degree of connection of the dump with the system of ecocorridors.

Conclusions

On the example of Lugansk region it is shown that the inclusion of dumps of coal mines and ore mining enterprises in local ecological networks with the status of regenerated territories will stimulate their afforestation, which will contribute to a radical reduction of the release of pollutants from the dumps. Implementation of contour-reclamation organization of their territory is important for the complex solution of the problem of soil erosion degradation and the distribution of pollutants in the agro-landscape.

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