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POLLUTION OF THE ROADSIDE ENVIRONMENT WITH DUST FROM ROAD SURFACE REPAIRS

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Abstract

The purpose of research work should be considered the practical aspects study of environmental pollution near highways with dust particles generated during repair work. The results of the study reflect the entire scope of research work carried out in order to determine the optimal composition of the concrete mixture for road repair work, which makes it possible to achieve a reduction in the emission of dust particles into the roadside environment and improve the environmental situation in the roadside. Also in this study, recommendations were proposed for the elimination of polluting factors and the elimination of negative consequences for the environment. The results and conclusions of this scientific study are of significant practical importance for road maintenance workers who professionally solve the issues of pavement repair, as well as for researchers conducting scientific research in the direction of studying environmental safety problems during road repair work.

Keywords:

Road surface;
Roadside environment;
Environmental pollution;
Road construction;
Road repair ecology.

1 Introduction

In accordance with the tendencies of sustainable development, improving the quality and durability of roads, and directly for the construction complex, it is necessary to develop and subsequently produce both energy-efficient building structures and materials, and energy-saving technologies for their industrial production. The main structural road material is asphalt concrete, which is sensitive to fluctuations in ambient temperature, which, together with mechanical effects from transport loads, causes its insufficient operational reliability under conditions of sign-changing temperatures and leads to the formation of various types of damage and deformation [1]. Taking into account all the minuses of asphalt concrete in modern road and airfield construction, high-tech concrete mixes are increasingly being used, which can provide strength and performance properties to coatings throughout the entire overhaul life. Such mixtures, along with high workability, should be characterized by a fast rate of strength development, high physical and mechanical properties and correspond to the class of "high performance concretes" (High Performance Concretes). All this is achieved through the use of modifier complexes, which include effective solvents, as well as such types of additives as fillers, hardening accelerators, additives that not only affect rheological properties, such as viscosity, but also those additives that allow you to pre-set the necessary properties building materials. Directly, the use of superplasticizers, microsilica derivatives of kaolin, etc. leads to a significant increase in the cost of modified concretes compared to standard types [2]. There is a statement that the composition and structure of complexly modified concretes determine the prospects for the emergence of negative properties: high shrinkage and unacceptable creep, a

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significantly reduced coefficient of elasticity, the possibility of cracking in road structures, and a decrease in frost resistance operating cycles.

At the same time, the growing problems of environmental pollution by road transport, as well as during the operation and repair of the roadway, require an early search and practical implementation of modern methods for improving the overall environmental situation that occurs during work related to road repairs and involves significant dust emissions into the surrounding roadside [3].

The roadside environment is a plant and animal habitat ecosystem, that is, they directly represent the world in which they exist. The impact that the repair of road surface has on the world around us is very multifaceted. In some cases, there is a change in the relief (as a rule, during repair work to a lesser extent than during the construction of new communication lines), but such types of repair work as the installation of drainage systems, various kinds of sewer collectors, punctures for various types of communications, affect underground bio ecosystems. And the impacts that roadsides are exposed to during repair and their operation often destroy the fertile soil layer, the groundwater level changes and such impacts often not only change, but destroy the bio system, while the flora tends to adapt, although undergoing changes, and the fauna often suffers the biggest changes. At the same time, that part of the flora and fauna that has adapted to life after the initial construction of the road once again experiences radical changes during the repair of the roadway. This implies the conclusion that the repair work has a direct impact on the change and pollution of the environment. It should also be noted the impact of repair work on human health, since the road system cannot be isolated from human habitats (after all, the road system itself is primarily designed to solve the logistical needs of a person). And, therefore, when developing the design part of the repair of the road surface, it is also necessary to take into account environmental issues. First of all, it is necessary to use materials that have the least impact on changing the environment; consider the issues of maintaining the natural balance and the restoration of the destroyed ecosystem at the site of ongoing repair work.

The use of concrete with the addition of nano-modifiers made on the basis of various production wastes during the repair of pavement – aggregated silicon dioxide from slag fillers of metallurgical plants, blast-furnace granulated slags, etc., defining the increased rates of dust emission during the repair of road surface, exacerbates the problem and encourages the search for new ways of its practical solution [4].

Currently, advanced domestic and foreign experience demonstrates the effectiveness of nano-modification technologies in road construction materials. It has been proved that the use of primary nanomaterials (carbon tubes) can improve the performance properties of asphalt concrete by up to 40 %, however, very few such studies have been performed [5]. In addition, numerous studies have established the effectiveness of the use of polymer-cement binders, which differ from conventional portland cement in improved physical and mechanical properties and durability. In Ukraine, as well as in European countries, studies were carried out to improve the performance properties of concrete by introducing fibrous additives into cement, such as polymer fibers, basalt fiber, TEC fly ash fiber (made in China) [6]. Concrete with the introduction of basalt fiber and fiber from TEC fly ash have higher strength, water and frost resistance.

To address the issue of environmental protection, it is necessary to initially consider the factors that adversely affect natural components. Determine the degree of their intensity and duration of exposure, their elimination after repair work. As well as forecasting the development of a negative impact on the environment. In this study, the problem is somewhat narrowed and does not fully include a full consideration of the negative impact of exhaust gases from working machines and mechanisms on the air pool surrounding this area. Also considerations of the full-fledged protection of water resources are excluded, which include surface and aboveground water layers from pollution, noise protection of animal and human habitats (due to the impact of noise emitted by machines and mechanisms in the area of repair work), soil protection and rational use of roadside lands, conservation and protection of flora and fauna, since all these issues require a separate in-depth study. The purpose of this scientific study is to determine the degree of influence of the material choice for road surface repair on the level of dust emissions into the roadside environment, as well as to assess the overall pollution level of the roadside environment with dust particles during road surface repair. To do this, it is necessary to solve the main problem – the choice of building material that has the least degree of negative impact on the environment.

2 Materials and methods

When performing research work within the limits of this scientific study, the method of issues system analysis included in its subject was used, which allows making an objective study of the pollution problems of the roadside environment with dust particles from the repair work of the road surface. The chosen method makes it possible to conduct a qualitative study of the environmental pollution problems during road works and to assess the environmental damage caused during the repair of road surface in general, in the context of the dust particles release during work and their settling on adjacent areas. The methodology of this scientific research involves the implementation of theoretical and practical research with the provision of basic statistical information on the results obtained, in order to compile the most qualitative and objective picture of this scientific research.

The basis of this research work is the numerous developments of domestic and foreign researchers of issues related to road construction and environmental pollution during dust emissions from road surface repairs. In order to create the highest quality and objective picture of research work, as well as to facilitate the perception of the information provided, all materials obtained from foreign sources and given in this scientific study have been translated into Russian. The methodological base of this research work is formed in careful accordance with the issues submitted for consideration, in order to cover them comprehensively and a qualitatively.

This scientific study was carried out in stages and included three parts:

1) In the first part of this research work, a theoretical analysis of research publications was carried out, revealing the issues submitted for consideration, in order to determine the currently relevant views of researchers on the choice of building material for the repair of the road surface and the practical resolution of improving the general environmental situation in the field of road pavement repair issues. Information about the number of vehicles and the corresponding data were taken from the statements of companies involved in the repair of the roadway on the example of the repair of the M-03 highway Kyiv - Kharkiv - Dovzhansky, km 482 + 600 TOV “Avtomagistra l - South” and PJSC “Alpservis”.

2) In the second part of this scientific study, practical developments were made to assess the degree of deterioration of the environmental situation in the field of road surface repair due to pollution of the surrounding area by settling dust particles as a result of repair work. At the same time, comparative evaluation studies of the results obtained in this research work were carried out in comparison with the results and conclusions of other scientists involved in the theoretical and practical consideration of all the issues included in the subject of this scientific work.

3) At the final stage of this research work, the conclusions drawn from its results are forming. In general, the conclusions of this scientific study are the results of theoretical and practical research carried out within the framework of the stated topic of this scientific study, and put an end to the study of environmental pollution near highways during the repair of the road surface, as well as assessing the actual and potential damage to the environmental roadside situations. In addition, the results and conclusions of this research work are of significant practical importance in terms of the potential improvement of the overall environmental situation in highway repair areas.

3 Results and discussion

One of the most harmful factors affecting the atmosphere is the emission of toxic substances by internal combustion engines of operating vehicles on a road section that is being repaired, such as nitrogen oxides, hydrocarbons, soot, lead, sulphur, and benzopyrenes.

Diesel engines (which are most common during repair work emit carbon dioxide and sulphur dioxide SO_2, which subsequently, dissolving in water, forms sulphuric acid. In this case, pollution occurs not only in the surrounding area, but also acid rain is possible far beyond the work area. Nitric oxide NO_2 contributes to photochemical smog.

Soot formed from hydrocarbons forms aerosols and, like acid rain, can disrupt the ecosphere far beyond emissions. The first hazard class is lead (its emissions). The concentration of pollutants for each source of pollution during the performance of work must be strictly regulated and must not exceed the maximum allowable standards established by regulatory authorities and approved by the relevant authorities. Subsequently, rehabilitation should be carried out. The list of pollutants occurring during the repair of the road in the internal combustion engine is shown in Table 1.

Table 1: Toxic substances contained in the emissions of internal combustion engines.

Type of pollutant	Impurity code	Hazard class	Norm MACm.r. [mg/m^3]	Norm MACm.s. [mg/m^3]
Carbon monoxide	0337	4	5,00	3.00
Nitrogen oxides NOx	0301	2	0.085	0.04
Carbons CmHn	0401	4	1.00	1.00
Soot	0328	3	0.15	0.05
Lead compound	0184	1	0.001	0.0003

At the same time, it should be taken into account that the concentration of spent emissions from internal combustion engines cannot be calculated according to the standards established for moving vehicles, since the transport is statically located and the moment of dispersion in the air basin, taking into account the size of the speed, is not taken into account here.

The data of the summary statements of the vehicles needs, road-building machines and mechanisms involved in the repair of the Kyiv - Kharkov - Dovzhansky highway are shown in Table 2.

Table 2: The number of machines and mechanisms involved in the repair of the considered section of the road.

No	Name of road construction equipment	Total
1	2	3
1	Dump trucks with a capacity of 40 [t]	6
2	Dump trucks with a capacity of 25 [t]	4
3	Medium motor graders 99 [kW/] 135 [h. p.]	2
4	Bulldozers 79 [kW] / 108 [h. p.] / when working on water management construction	2
5	Bulldozers 79 [kW] / 108 [h. p.] / when working on other types of construction	2
6	Trailed road rollers on pneumatic wheels 25 [t]	4
7	Rollers road self-propelled smooth 8 [t]	2
8	Rollers road self-propelled smooth 13 [t]	2
9	Road rollers, self-propelled, smooth on pneumatic wheels 16 [t]	2
10	Cranes 6.3 [t] on a car when working on other types of construction	2
11	Cranes 25 [t] on caterpillars when working on other types of construction	1
12	Cranes 25 [t] on pneumatic wheels when working on other types of construction	1
13	Drilling machines with a drilling depth of 3.5 [m] on a tractor 85 [kW] / 115 [h. p.]	2
14	Watering machines 6000 [l]	4
15	Trailed scrapers 8.0 [m^3] / with caterpillar tractor when working on other types of construction	2
16	Crawler tractors up to 59 [kW] / 80 [h. p.]	2
17	Caterpillar tractors in other construction applications 79 [kW] / 108 [h. p.]	1
18	Tractors on pneumatic wheels when working on other types of construction 40 [kW] / 55 [h. p.]	1
19	Tractors on pneumatic wheels when working on other types of construction 59 [kW] / 80 [h. p.]	1
20	Pneumatic rammers when powered by a compressor	6
21	Single-bucket diesel excavators 0.65 [m^3] on caterpillars when working on other types of construction	4
22	Hole diggers	4

At the same time, the maximum allowable emission of harmful substances into the atmosphere is calculated taking into account the increase in traffic intensity due to an increase in freight turnover and taking into account the work of construction mechanisms during the rehabilitation of the road. The calculation of exhaust gas emissions (ICE - Internal combustion engine) during the operation of machines and mechanisms for the period of reconstruction of the Kyiv - Kharkov - Dovzhansky highway is shown in Table 4.

Table 4: The amount of emissions from the operation of machines and mechanisms for the period of reconstruction of the highway Kyiv - Kharkiv - Dovzhansky.

No	Source of harmful substances emission	Type of fuel	Fuel consumption [ton]	Emissions for the construction period [ton]					Total [ton]
				CO2	CH	NO2	C	SO2	
	Specific emissions [ton] / [ton] of fuel	gasoline		0,01	0.03	0.04	0.05	0.02	
		diesel		0.07	0.1	0.04	0.005	0.002	
1	Motor grader 99 [kW]	diesel	7.440	0.521	0.744	0.298	0.037	0.015	1.614
2	Bulldozers 79 [kW] / 108 [h. p.] / when working on water management construction	diesel	1.296	0.091	0/130	0.052	0.006	0.0026	0.281
3	Bulldozers 79 [kW] / 108 [h. p.] / when working on other types of construction	diesel	80.014	5.601	8.001	3.201	0.400	0.160	17.363
4	Trailed road rollers on pneumatic wheels 25 [t]	diesel	23.100	1.617	2.310	0.924	0.116	0.046	5.013
5	Rollers self-propelled 8 [t] / 13 [t] / 16 [t]	diesel	42.683	2.988	4.268	1.707	0.213	0.085	9.262
6	Cranes 6.3 [t] on a car	diesel	0.209	0.015	0.021	0.008	0.001	0.0004	0.045
7	Cranes 25 [t] on caterpillars	diesel	1.779	0.125	0.178	0.071	0.009	0.004	0.262
8	Cranes 25 [t] on pneumatic wheels	diesel	0.241	0.017	0.024	0.010	0.001	0.000	0.035
9	Drilling machines with a drilling depth of 3.5 [m] on a tractor 85 [kW] / 115 [h. p.]	diesel	0.055	0.004	0.005	0.002	0.0003	0.0001	0.012
10	Watering machines 6000 [l]	gasoline	422.088	4.221	12.663	16.884	21.104	8.442	63.313
11	Caterpillar tractors up to 59 [kW]/80 [h. p.]	diesel	0.172	0.012	0.017	0.007	0.0009	0.0003	0.037
12	Caterpillar tractors in other construction applications 79 [kW]/ 108 [h. p.]	diesel	16.170	1.132	1.617	0.647	0.081	0.032	3.509
13	Tractors on pneumatic wheels when working on other types of construction 40 [kW] / 55 [h. p.]	diesel	0.129	0.009	0.013	0.0052	0.0006	0.0003	0.028
14	Tractors on pneumatic wheels when working on other types of construction 59 [kW] / 80 [h. p.]	diesel	0.058	0.004	0.006	0.002	0.0003	0.00012	0.013
15	Excavators 0.65 [m^3]	diesel	66.268	4.630	6.627	2.651	0.331	0.133	14.380
16	Trailed scrapers 8.0 [m^3/s] with caterpillar tractor	diesel	0.713	0.050	0.071	0.029	0.004	0.001	0.155
17	Hole diggers	diesel	0.713	0.050	0.071	0.029	0.004	0.001	0.155
TOTAL for the construction period				21.048	36.702	26.499	22.306	8.923	115.478

After reviewing Table 4, it is recommended to carry out protection measures against exhaust gases after the start of work:

1) technical,
2) constructive,
3) protective,
4) organizational.

Also, during the road repair, dusting of the air occurs.

It is necessary to apply measures to protect against dust formation and dust in general, namely:

1) the device of a bypass road covering of a sickle-shaped profile,
2) wetting of surfaces and periodic watering with water,
3) issuance of personal protective equipment to employees.

Talking about the organization of the sanitary protection zone, it is necessary to consider the classification of the road itself. What class does it belong to and, if necessary, calculate and plant protective plants and trees. The issue of groundwater protection must also be addressed at the design stage. The presence of groundwater is considered, and during repair work on bridges and overpasses, underlying rivers and other water bodies are considered. It is necessary to provide for the installation of drainage systems (pipes), considering the estimated flow rate and throughput, as well as, if necessary, the installation of pedestrian crossings. But one of the most significant factors influencing environmental pollution is the influence of the building material used, since its influence will continue in time and after the completion of repair work during the operation of the roadway. And the most common material that makes up the roadway is asphalt concrete and its derivatives.

The ecological development of building technologies in the production of asphalt-concrete mixtures and the creation of constructs from them is significantly influenced by two main values: first of all, the production of high-quality concrete, and at the same time, the reduction of labor and energy costs during its production. Over a long period of time, these two factors have remained contradictory, because in order to consistently obtain high-strength, durable concretes, their composition should be

designed with a low water-cement ratio parameter, which determines the production of rigid concrete mixtures that require significant energy costs during their mixing, and also laying and vibrating compaction in molds. The latter contributes to a very rapid increase in the labor costs of the technological process. At the same time, the possibility of obtaining highly mobile concrete mixtures was achieved mainly by increasing the mixing water cost, which leads to a decrease in the strength and practical operation time of the concrete pavement. Such contradictions were largely resolved with the introduction of effective additives in the form of plasticizers and superplasticizers in the 60 - 70 of the last century. Their use in concrete made it possible to obtain highly mobile (cast) concrete compositions and concretes with high physical, mechanical and operational parameters on typical portland cements and aggregates, due to the two most important effects: plasticizing and water-reducing. However, despite the obvious advantages in obtaining concrete mixtures of high mobility, there were also significant disadvantages. Thus, the bulk of superplasticizers significantly slowed down the setting and concrete hardening, especially if the doses were high.

Very often, the superplasticizers of the initial generations did not guarantee the necessary preservation of the concrete workability during transportation to the place of molding within 1 - 1.5 hours. When concrete mixtures were pumped by concrete deliverers or concrete pumps to the workplace at a distance of more than a quarter of a kilometer, they often delaminated, which created heterogeneity in building structures. From such positions, the granulometric composition of the mineral part of concretes must always meet the requirements for pumped concretes. When a concrete mixture of a dense structure is deformed, which is formed by the continuous granulometry of aggregates, its particles can float in layers (one layer on another), not lingering in voids, even with proper vibration.

It should be noted that an important role in the highly mobile concrete mixtures technology development is given to the scientific foundations formed as a result of a large scientific studies number and proven by practice of the scientific basis for modifying concrete with polyfunctional additives-modifiers. With the advent of third-generation superplasticizers, the practical use of highly dispersed silica-containing materials of technogenic origin, primarily microsilica (MS), a powerful leap was observed in concrete technology. The optimal ratio of these modifier additives, and, if necessary, pairing other organic and mineral materials with them, determines the possibility of directed control of the rheological characteristics, modifications of the structure of cement stone at the concrete mixes micro level in such a way as to impart properties that guarantee high operational strength of asphalt concrete and concrete structures.

In matters of concrete production and assessment of the degree of pollution of the roadside environment with dust particles during the repair of pavement having a concrete and asphalt concrete base, a promising direction is the use of nano-additives in the construction of concrete, which do not have significant binding characteristics. But at the same time, in a significantly crushed form, as well as in the presence of incoherent water, they can enter into a chemical reaction with calcium hydroxide at a temperature of 15 - 25 ºC with a transition to compounds with astringent properties:

$$2\,SiO_2 + 3Ca\,(OH)_2 \rightarrow 3CaO \cdot H_2O\ , \tag{1}$$

$$Al_2O_3 + 3Ca\,(OH)_2 + 3H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O\ . \tag{2}$$

The structure-forming role of carbon nano-additives consists in a decrease in the time of the induction period of structure formation as a result of hydrolysis products adsorption and an increase in time intervals that contribute to an increase in the liquid phase. Thus, chemical reactions are activated that cause hydration of the binder, contributing to the formation of hydrates, which are formed with an increase in volume and quantitative indicators, while the share ratio of calcium hydrosilicates of the CSH (I) type with a C/S ratio of 1.0, which are formed instead of the primary ones, increases. crystalline hydrates, which contributes to the densification of the structure at the contact with the nano-filler with a significant increase in the microscopic hardness of hydrate aggregates [7].

When conducting a comprehensive assessment of emissions into the surrounding space during road works, one should take into account the complex relationships that arise in the context of the preparation of building material for the construction and repair of sections of the roadway and its removal and replacement during repair work.

In this context, the properties of concrete mixtures used in the repair of pavement are of significant importance. The classification of concrete mixtures according to the parameters of quality and durability of practical use is shown in Table 5.

Table 5: Classification of concrete mixtures according to the parameters of quality and durability of practical use.

Name of concrete mixture	Designation	Scope of concrete and their purpose
With high mobility (Flowability Slump-Flow)	SF1 (550 - 650 mm)	Unreinforced or reinforced concrete structures - road and airfield pavement slabs, pipelines, tunnel linings, foundations
	SF2 (660 - 750 mm)	Most road and airport facilities
	SF3 (760 - 850 mm)	Shotcrete, shotcrete concrete
High viscosity (Viscosity)	VS1/VF1 (viscosity less than 8 seconds)	Structures subject to high requirements for the quality of the surface of road and airfield structures
	VS2/VF1 (viscosity 9 - 25 seconds)	Structures of foundations and other underlying layers
Resistant to delamination (Segregation resistance)	SR 1 (stratification not more than 20 %)	Road and airfield structures
	SR 2 (stratification not more than 15 %)	

The classification presented in Table 5 assumes the division of concrete mixtures used for pavement repair into three types:

- mixtures with a low ratio of water-binder and mixtures with a content of dispersed materials above the norm, used to increase plastic viscosity,
- mixtures with a modifier that increases the degree of viscosity - in comparison with the previous mixtures, they require more superplasticizers per specific part, a higher value of the W / W ratio to form a stable filling (penetrating) ability.

There may be issues related to the incompatibility of viscosity modifiers with superplasticizers:

- combined mixes - powder type concretes with a small addition of a viscosity modifier.

The use of various types mixtures determines the differences in the distribution of dust emissions during repair work on pavement. The main components of the concrete mixture, incompatible with some modifying elements and plasticizers, cause significant pollution of the surrounding roadside space through uncontrolled dust emissions.

Nowadays, a simplified method for designing the composition of modified concrete has been developed and implemented, the basis of which one of the conditions is the development of such a technological method, which will achieve the maximum packing factor of coarse and fine aggregates - (packing factor PF). This design reduces the emission of dust particles into the environment during road surface repairs [8]. The strength is provided by the framework of the aggregates glued together with the cement paste in the hardened state, while the technological properties of the mixtures are provided by the cement paste in the freshly prepared state. Obviously, the packing factor PF affects the content of aggregates. A higher PF value causes a higher content of coarse and fine aggregates, reducing the amount of binder. Accordingly, the convenience of laying the concrete mix, its ability to self-compact, as well as the compressive strength of concrete will decrease. On the other hand, a low PF value results in increased concrete shrinkage. Table 2 presents the characteristics of nano-modified concrete mixtures developed in different countries of the world, the practical use of which in road repair works reduces dust emissions into the roadside environment during repair work on road pavements. The characteristics of nano-modified concrete mixtures are shown in Table 5, the practical application of which in road repair works reduces dust emissions into the roadside environment.

Table 6: Characteristics of nano-modified concrete mixtures.

Concrete mix components	Average consumption per 1 m^3 of concrete mix in different countries			
	Ukraine	USA	EU countries	Indo - China
Water [l]	135	140	150	161
Portland cement [kg]	530	357	280	330
Modifiers (nano-carbon tubes)	70 (nano-carbon tubes)	119 (blast-furnace granulated slag)	245 (ground limestone)	150 (high calcium ash)
Fine aggregate [kg]	751	936	865	309
Coarse filler [kg]	789	684	750	455
Additive super-plasticizer [kg] [l]	9	2.5	4.2	0.92

Thus, a reduction in the volume of dust emissions during repair work on pavement can be achieved by selecting the components of the concrete mixture used in such work. The quality of the road surface does not suffer. The increasing progression of environmental pollution requires the urgent application of complex measures with statistical accounting for harmful emissions, including dust waste from repair and construction road works. A significant part of the negative impact on the environment is made not only by road transport and other types of moving vehicles. The main share of pollution falls on the exhaust gases of internal combustion engines, which, as in construction equipment, are used in cars. However, during the long-term use of roads, other processes also contribute to environmental pollution, such as repairing the roadway, laying concrete pavement during the construction of highways, as well as repairing road surface. The issue of taking into account and evaluating the contribution of such constituent elements to the total volume of emissions from the auto-road complex (ARC) has not been fully studied [9].

Road repair work has traditionally been a constant emissions source of a number of toxic substances into the atmosphere, some of which have carcinogenic properties or exacerbate local environmental problems [10]. Dust emissions accompanying repair and construction work in general, as well as repair work of pavement, in particular, should rightfully be classified as such. Annual dust emissions into the environment, which invariably accompany road repair work, are a source of increased environmental hazard for areas adjacent to highways, contributing to an increase in environmental pollution and the development of chronic respiratory diseases and residents of nearby areas.

On the one hand, nano-modified concretes have long been widely used in road construction as materials that increase the efficiency of roadway operation and partly reduce emissions into the environment [11]. On the other hand, these mixtures provide a significant reduction in energy consumption and labor intensity of the pavement repair process, which is a determining factor when deciding whether to use this type of pavement in construction and repair work.

Numerous practical observations have established that dust particles appear on highways and adjacent territories for the following reasons: abrasion of the roadbed, gradual deterioration of car tires, car exhaust gases, wear of car parts, road repair and construction works, soil erosion of adjacent territories. At the same time, periodic processes of removal and entry of particles are formed on the roadway. The entrainment of particles is formed by physical factors: wind and air volumes movement. Particle entrainment - the occurrence of exhaust gas particles, the gradual destruction of car tires, road surfaces and others [12]. The most massive are dust emissions during the repair work of road surface and the replacement of the highway pavement. Repair of pavement is carried out using special road machines to remove the damaged section of the road surface. As a rule, this equipment is used in places of maximum damage to the road surface, in places where vehicles are descending, immediately before intersections, as well as in areas with the most intense traffic. Approximately 90 % of dust particles released during the repair of the road surface using special tools have a size of less than 2.5 microns.

Rising dust particles are in turbulent motion and their aerodynamic diameter ranges from several tens of nanometers to tens of micrometers [13]. An integral assessment of the degree of pollution of the environment is carried out using an indicator - the air quality index (AQI), in Ukraine and other CIS countries, along with AQI, a complex indicator is used - the air pollution index (API) [14]. The air quality index makes it possible to provide information on the nature of air pollution in the most simple and visual form. The calculation of the API is based on the fact that with parameters at the MPC (maximum permissible concentration) level, all hazardous air impurities equally affect a person, and with a subsequent increase in concentration, the level of their harmfulness increases at a different rate, which is determined by the hazard class of the substance.

In the areas of repair work with resurfacing of the roadway and during the repair of road surface, the AQI indicator of ambient air pollution is in the range of 25 - 86 units, while the extreme load on the roadway, which subsequently leads to the need for its repair, ranges from 22 to 50 % index Tom Tom, developed by the transport company of the same name. With a high intensity of road surface repair work, the AQI index may increase to 120 - 140 units and higher.

Dust emissions into the roadside zone during the repair work of pavement are in no way related to the emissions of toxic substances from automobile engines and they should be considered as a momentary factor, which, however, is of great importance from the point of view of the general environmental situation deterioration in the places of repair and construction work on roadway and health hazards for citizens living near the repair area [15]. The results of numerous observations allow

us to conclude that there is a non-uniform distribution of dust particles in the emissions areas, which depends on the intensity of the repair work and the technological means used in them.

Also, special attention should be paid to the quality and technological composition of concrete used in construction and repair road works. In concrete mixtures using naphthalene (melamine) formaldehyde formations (condensates and polycondensates), with an increase in the adsorption of the superplasticizer on the minerals that make up the cement and other hydration products, the initial mobility increases. But, after some time, the mobility of the mixtures decreases, which is due to the lack of a non-cohesive superplasticizer in the volume of the pore fluid, which is required for the electrostatic stabilization of the disperse system. A similar state of affairs is in the case of using polycarboxylate polymers - the higher the concentration of C3A, the higher the critical volume of the additive to obtain a given plasticizing effect. Accordingly, dust emissions during repair work and the use of such a coating also change significantly, as do the pollution parameters of the roadside environment.

During the operation of road maintenance equipment, which is used in the repair of road surface, a lot of pollutants are also emitted into the atmosphere, and when fuel oil is used as fuel for such units [16]. In the event that gasoline is used as the main fuel for them, soot and inorganic substances are actively emitted into the atmosphere, which are combustion products of this gasoline of the corresponding grade.

During the preparation for asphalt concrete mixtures laying as elements of a new road surface, dust fractions are actively emitted into the atmosphere, which are products of fuel oil combustion, as well as bitumen vapor particles. This determines the urgent need to prevent the increase in emissions of such substances into the atmosphere through the development and practical implementation of methods for limiting dust emissions during the repair of road surface. In order to protect the surrounding roadside area during maintenance and construction work on the roadway, the use of dust collectors is recommended to reduce dust emissions into the environment. The discharge of purified gas into the atmosphere in the cyclone is carried out using a removable compression fitting, a common collector and directly into the exhaust pipe. The advantages of such an industrial one are its low cost and simplicity of design. The disadvantages of dust collectors are their high aerodynamic resistance 50 - 80 kgf/m^2, the dimensions of which are 4 - 5 m in height, low cleaning efficiency from dust particles smaller than one micron. The cyclone emits coarse dust, which does not pose a significant danger from an environmental point of view. Dangerous for living organisms, including humans, fine dust with a particle size of less than 10 microns is separated exclusively by wet apparatus and fabric-type respirators.

In addition, in places with increased dust emissions into the atmosphere during repair work, in order to reduce the pollution level of the surrounding roadside space, it is recommended to use irrigation systems that provide abundant wetting of the surrounding air with water. This measure allows several times to reduce the volume of dust emissions into the atmosphere, which significantly reduces environmental risks for residents of the adjacent territories. Due to the rotational movement of the irrigation system plates, dust particles coagulate both on the surface of these plates, as well as when gas passes through the holes [17]. Rotary movements of the coagulation plates completely exclude the possibility of dry non-irrigated areas, preventing the adhesion and accumulation of dust particles on the plates, and also contribute to the dispersion of the liquid into more fractional drops, eliminating the possibility of subsequent occurrence of direct-flow jet streams. When passing through the holes of a series of sequentially placed plates, the dust coagulates more and more densely into liquid sludge, which subsequently flows into the conical bottom, and the air, freed from dust particles, is directed between the cylindrical walls of the housing and enters the atmosphere. Air purification must be carried out by increasing the number of coagulation plates, since dust will coagulate in a two-phase dusty air flow with an increase in the effect [18].

Upon reaching certain indicators of the road surface evenness after the completion of repair and construction work to replace damaged road sections, a qualitative reduction in dust emissions into the atmosphere, generated due to abrasion of car tires during the movement of vehicles, is achieved. This fact can serve as direct evidence of the justification for introducing requirements for indicators of achieving evenness of the road surface as a result of repair work to replace the pavement [19].

The properties of the concrete used in the repair of road surface are essential in assessing the level of dust emissions into the atmosphere directly during repair work. Particular importance in this context should be given to the mineral additives used in the manufacture of cement and concrete mixtures. Various types of additives used can affect not only the rheological properties of the concrete and cement-sand mixture, but also change the degree of hydration of portland cement, the strength

and permeability of hardened concrete, reduce the causes of cracking, especially under the influence of thermal factors, reduce the impact of an alkaline environment on silica, and also resist when exposed to sulphate aggressive environment. Among the active mineral additives from industrial waste - TPP fly ash, is used in the compositions of nano-modified concretes to reduce water demand and increase the fluidity of concrete mixes, due to the peculiarities of spheroidal particles; among fillers is used to increase the viscosity of the concretes mortar component, nano-powder additives have become widespread in Europe.

Nano-dispersed materials, such as nano-carbon tubes, have a positive effect on the rheological properties of cement systems. Their particles, being distributed in the total volume of the cement dispersion, entering into a chemical reaction, together with larger particles create a spatial three-dimensional framework consisting of chains and aggregates with versatile coagulation bonds [20]. In this case, the rheological properties can change cardinally: the coefficient of structural and plastic viscosity, cohesion and thixotropic characteristics of enriched solutions increase, and directly, as a result of physical and chemical reactions occurring during the arrangement of the necessary mixture, the strengthening of interconnected interactions. At the same time, by correctly programming and maintaining the scheduled deadlines, it is possible, under certain conditions and optimal dosage, to reduce the water demand of concrete mixtures or increase their mobility with the help of silica [21].

Thus, the ecological situation in the zone of dust emissions from the repair work of the road pavement, due to the repair of road surface, is a complex component of many closely interrelated factors that determine both the nature of dust emissions and their duration, as well as the degree of impact on the environmental situation in the attached roadside environment, as well as the impact on the health of citizens living in this environment.

4 Conclusion

Basing on the results of this research work, the following conclusions are formulated:

- The main factors influencing environmental pollution during road repair work are considered. The study showed the closest relationship between the ecosystems of human and animal life and, accordingly, the relationship of the mutual influence of negatively influencing factors.
- Pollution of the roadside environment with dust particles from road surface repair is caused by many interrelated factors that determine both, the nature of the pollution itself and its frequency, as well as the influence degree of polluting factors on the life and health of citizens who live in the pollution zone. First of all, the level of pollution is determined by the type of concrete mixture used in the preparation and conduct of road repair works related to the need to repair or replace a damaged section of the roadway, as well as to change the design of the road surface directly in the area of such work.
- In addition, the nature of the repair work and the type of road equipment used in these repair work are also of significant importance, since the equipment has a direct impact on the pollution of the surrounding space during repair work. At the same time, it is possible to achieve a significant reduction in harmful dust emissions into the roadside environment through the practical use of special dust collectors during repair work, as well as irrigation systems, which make it possible to temporarily reduce the level of atmospheric dust emissions directly in the area of repair work.
- Polluting factors affecting the environment were considered on the example of the repair of the Kyiv - Kharkov - Dovzhansky highway. To the main polluting factors considered in the study, a solution was proposed to eliminate them. When considering the materials used in the repair of the roadway, their impact on the environment was studied and factors were identified, the elimination of which partially solved the issue of emissions.
- Comprehensive consideration of all the above factors is mandatory in terms of determining both the emissions level of harmful dust particles into the roadside environment during road surface repair work, and assessing the degree of environmental problems that arise during this kind of repair work. Pollution of the roadside environment with dust emissions has a significant impact on the general ecological state of the territory in the area of repair work and largely determines the level of morbidity in the surrounding areas due to their pollution.

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