Інженерія використання та відновлення довкілля
Engineering of use and restore the environment

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Sustainability of the use of agricultural machinery and its on the environment

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The main types of negative impact of technology on the natural environment are gaseous, solid and liquid emissions, heat emissions, resource depletion. As a result of repeated movement of machines across the field, there is a significant over compaction of the soil, which spreads to a great depth (up to 100 cm), and machine tracks cover up to 80.0% of the field. Soil density increases by 20.0-40.0% under the influence of heavy machinery. Exhaust gases are the main source of toxic emissions. They are a mixture of gaseous products of complete and incomplete combustion of fuel, excess air and various trace impurities. Diesel engines are extremely toxic due to their high content of NO_x, benzene, aldehydes and soot, although they have significantly lower CO and CH emissions compared to gasoline engines. Carbon monoxide (CO) is the leader among harmful substances in terms of absolute emissions. Its figure is 10.3 million tons per year. Nitrogen dioxide (NO_2) is on the second place with 1.8 million tons per year. Hydrocarbons (CH) are on the third place with 1.5 million tons per year. The priority belongs to NO_2, lead (Pb), sulfur dioxide (SO_2) and soot particles in terms of environmental hazard. It is necessary to ensure the reduction of emissions of these substances in the first place. Emissions of SO_2, CO and benzopyrene play a significant role in air pollution. At first it is necessary to ensure the reduction of emissions of these substances.

Keywords*: Environment; Agricultural machinery; Environmental impact; Emissions; Soil*

Introduction. Nowadays, the agriculture has become a powerful factor of environmental impact along with the industry. The use of machinery in agriculture entails consequences that negatively affect an environment. Prevention and minimization of these consequences are the most important tasks of "greening" the agricultural sector (Tirion, 1999).

The main types of negative impact of technology on the natural environment are gaseous, solid and liquid emissions, heat emissions, resource depletion.

Tractor emissions are in first place in terms of the quantitative content and degree of negative impact on humans, flora and fauna (Siedlecki et al., 2017).

At present, the issues of increasing the reliability of equipment, improving working conditions, reducing injuries and morbidity remain relevant for agricultural production. Leading manufacturers of tractors and agricultural machines pay special attention not only to improving designs and increasing the reliability of machines, but also to eliminating their harmful effects on the environment and humans. The need to improve occupational safety in crop and livestock farming, an increase in energy saturation, an emergence of new equipment and technologies as well as a widespread use of mobile machines with diesel engines in the aggregates requires the development of engineering methods and technical means for cleaning exhaust gases from toxic components (Housden, 2005; Jorgensen, 2012).

Soil erosion is also an important problem in agriculture. Lands used for the production of agricultural products, arable land, hay fields, pastures are classified as land (agricultural) resources. Lands that provide the world's population with most of the food products make up only 13.0% of the land surface.

The process of increasing the area of land used for growing crops has been going on throughout the history of mankind. Territories were deforested, wetlands were drained and deserts were irrigated. But at the same time, people were already losing their agricultural land. The area of arable land was about 4.5 billion hectares before the intensive development of agriculture. Currently, there are only 2.5 billion hectares. Almost 7 million hectares of arable land are

irretrievably lost every year, which means a loss of the life base for 21 million people (Kanianska, 2016).

The soil does not receive enough organic fertilizers, which are important for the formation of humus, maintenance and improvement of the soil structure. This is due to the steady reduction in the number of livestock, pigs and poultry. This leads to a decrease in the production of organic fertilizers by the livestock industry (Maji et al., 2020). For a number of years, agricultural enterprises have not compensated for the nutrients taken out by the crop (Daxini et al., 2019). This causes an excessive removal of nutrients from humus for the formation of a crop, leads to a deterioration in the quality of soils, the accumulation of nitrates in food, as well as pollution of water bodies. The most important problem is the deterioration of the economic fertility of soil, which often causes irreparable damage to the land. A logical continuation of this process is a drop in yield and, as a result, a decrease in the gross yield of products, which in turn negatively affects the financial results of agricultural enterprises.

It is necessary to link the environmental conditions, terrain, modes of operation of diesel engines, types of work performed, in-cylinder processes with the formation of nitrogen oxides, carbon monoxide, hydrocarbons, soot and particulate matter, aldehydes and benzopyrene in the context of the use of agricultural mechanization means, when considering the problem of reducing the environmental impact of mobile equipment on the environment. The above processes are implemented by establishing compliance of the levels of harmful emissions with the standards due to the maximum permissible concentrations and maximum permissible emissions (Nicolae et al., 2013; Sugozu et al., 2010).

The issues of the environmental friendliness of all production and technical means are becoming increasingly important as the role of technology in the interaction of people with nature increases. Environmental friendliness is understood as such a state of the source of danger, in which its permissible impact on the technosphere and (or) the biosphere is observed in terms of life safety.

Materials and Methods. The issues of the means assessment to reduce the harmful emissions of diesel from mobile machinery can be solved with different reliability by many methods. The main requirements for the assessment method are data reliability, ease of operations, comprehensiveness and clarity of assessment criteria, the ability to check the selection results by other methods and use them in the resulting selection. The methods of the theory of operations, their principles and methodology were used as the basis for the choice of assessment. In contrast to similar techniques, a universal approach is considered and reasonable groups of criteria are identified. The generalized criterion has the form of the weighting factors of environmental, economical, technical and economical, technical and technological and operational criteria.

Results and Discussion. It was found that large-scale use of machinery in agriculture contributes to the growth of productivity and labor efficiency (Fig. 1).

However, it is also associated with negative environmental consequences (Tab. 1).

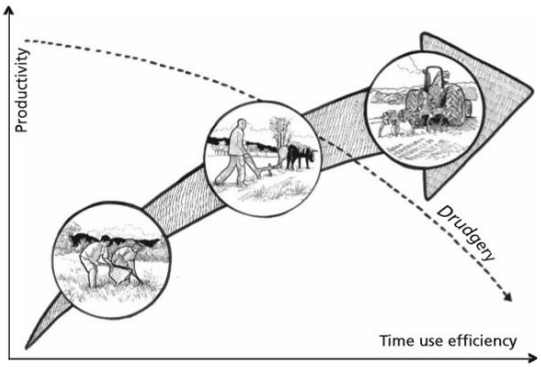

Figure 1. Mechanization of agriculture and its potential for reducing the labor intensity of manual labor and increasing labor productivity.

The applied technologies for growing agricultural crops provide for multiple impacts of the chassis of tractor machinery units on a soil.

A significant overcompaction of the soil, which spreads to a great depth (up to 100 cm), occurs under the influence of a repeated movement of machines across the field. As a result, machine tracks cover up to 80.0% of the field. Soil density increases by 20.0-40.0% under the influence of heavy machinery. The suppression of the activity of soil microorganisms, overconsolidation of the soil and disturbance of its structure, the demolition of ground soil by water and wind are negative consequences of the impact on the arable land of the running systems and working organs of tillage implements (machine soil degradation).

A serious consequence of soil compaction is an increase in its resistivity. The resistivity is largely dependent on reconsolidation of the soil by various propulsion devices and suspensions. It corresponds to the effort spent on cutting the seam, turning it over and rubbing the soil against the working surface of the equipment.

Overconsumption of fuel increases significantly due to an increase in soil resistance. In addition, soil crumbling worsens with overcompaction. The arable land becomes blocky, which leads to uneven embedding of seeds, a decrease in their field germination. As a result, a significant crop shortfall occurs.

The high density of the soil leads to a sharp deterioration in its physicochemical and agrophysical properties. Compacted soils offer great resistance to the penetration of plant root systems into them. The water-air and nutrient regimes deteriorate in such soils and erosion processes develop.

The optimum soil density (bulk density) is 1.1 g/cm^3. An increase in soil density by 0.1 g/cm^3 leads to a shortage of 6.0-8.0% of the yield. Total yield losses due to soil compaction on black earth reach 45.0% per year. The grain yield is reduced by 20.0% only due to soil overconsolidation, and the potato yield is reduced by 40.0-50.0%.

Measures to reduce soil compaction include:
- organizational and technological measures;
- agrotechnical methods to increase the resistance of soils to compaction and decompaction;
- improvement of the running systems of agricultural machinery with bringing the pressure on the soil to permissible values.

Table 1. Production processes and its possible negative consequences

Manufacturing processes	Negative consequences
1. Use of mobile energy means(cars, tractors, self-propelled agricultural machines)	- chemical, mechanical and acoustic pollution of the atmosphere; - pollution of the environment with liquid oil products; - compacting and destructive action on the soil as a result of pressure, dynamic action and vibration.
2. Soil cultivation	- development of water, wind and technical erosion; - the formation of a plow sole: growing conditions of plants deteriorate; - increased tractive effort as a result of soil compaction.
3. Application of mineral and organic fertilizers and plant protection	- pollution of water and soil with chemicals and disease-causing organisms; - the negative impact of pesticides on living organisms and ecosystems in general.
4. Cultivation and harvesting of roots and tubers	- development of erosion, soil compaction; - removal of soil from the field during transportation of insufficiently peeled roots and tubers; - damage to tubers: loss of production during storage.
5. Harvesting of grain and forage crops	- quantitative losses of cereals: improved nutritional conditions for pests; - loss of green mass when it is loaded onto vehicles; - quality losses: crushing and injury of grain; - death of animals under the knives of the mower when the harvesting units move into the drive.
6. Drying, cleaning, sorting and storage of grain and seeds. Getting of herbal flour	- environmental pollution by flue gases during the drying process; - obtaining insufficiently cleaned seed as a result of poor-quality cleaning: increased contamination of crops; - damage to grain and seeds and loss of products during storage.
7. Operation of the machine and tractor fleet	Environmental pollution and destructive effects on its components as a result of: - the use of energy-intensive machines with a large mass and high speed; - the presence of faults and shortcomings in the organization of the use of MTP; - carrying out maintenance and technical maintenance in the absence of appropriate equipment and special sites; - deficiencies in the organization of the oil industry (poor condition of tanks, dispensers, etc.); - lack of warm heated rooms for diesel cars and tractors; - environmental pollution with metals due to corrosion during storage of agricultural machines and untimely delivery of decommissioned equipment.
8. Land reclamation	- drainage: destruction of the fertile soil layer, lowering the level of groundwater, destruction of natural ecosystems; - irrigation: waterlogging and soil salinization; rise in the level of groundwater; destruction of the fertile soil layer with increased intensity of rain created by sprinkler units.
9. Mechanization of production processes in animal husbandry	- pollution and contamination of the environment with manure; - environmental pollution during washing of milking equipment and dairy equipment, during washing of roots and tubers; - air pollution by gases generated during the life of animals and the decomposition of manure, as well as dust and microorganisms during ventilation of premises.

Over 5 million tons of harmful substances per year are emitted only by diesel engines of tractors and combines in Ukraine. Emissions of automotive vehicles with diesel engines for the year are presented in Table. 2.

Accidental and operational spills of fuel and lubricants pose a serious hazard. Environmental pollution from battery acid, preservatives, detergents, coolants and other operating materials, as well as corrosion products, is increasing everywhere.

Copper, vanadium, molybdenum, nickel and chromium are released into the air and soil when the brake pads are abraded. Abrasion of tires is accompanied by the release of cadmium, lead and zinc into the soil. The special danger of these emissions is that they contain soot, which contributes to the deep penetration of heavy metals into the human body. A data presented in Table 3 shows volume of solid emissions produced by automotive vehicles per one year in Ukraine.

Table 2. Emissions of diesel engines of automotive vehicles in Ukraine for a calendar year

Type of equipment	Emissions of harmful substances, million tons				
	nitrogen oxides	carbon monoxide	hydrocarbons	sulfur oxides	solid particles
Tractors	1.50	0.80	0.15	0.10	0.06
Self-propelled vehicles	1.20	0.64	0.12	0.08	0.03
Combines	0.30	0.16	0.03	0.01	0.01
Total	3.00	1.60	0.30	0.19	0.10

Table 3. Solid emissions of automotive vehicles in Ukraine per year

Wear products of tires, brakes, thousand tons	90
Tires, million units	30
Metal, million tons	3

The combustion of 1.0 kg of diesel fuel releases about 80.0-100.0 g of toxic components (20.0-30.0 g of CO; 20.0-40.0 g of NO_x; 4.0-10.0 g of CH; 10.0-30.0 g of SO_x, 0.8-1.0 g of aldehydes; 3.0-5.0 g of soot, etc.). The contribution of diesel emissions from vehicles to the total concentration of nitrogen oxides in the atmosphere is about 20.0-26.0%. Diesels are extremely toxic due to the increased content of NO_x benzene, aldehydes and soot, despite the fact that compared to gasoline engines they have significantly lower CO and CH emissions. Carbon monoxide (CO) is the leader in absolute emissions among harmful substances (10.3 million tons per year). Nitrogen dioxide (NO_2) is in second place (1.8 million tons per year). Hydrocarbons (CH) are located on the third place (1.5 million tons per year). Priority belongs to NO_2, Pb, SO_2 and soot particles in terms of environmental hazard. It is necessary to provide the reduction of emission of these substances at first. Emissions of SO_2, CO and benzopyrene play a significant role in air pollution. A serious danger is also posed by asbestos dust, which is a part of friction materials. A dust is emitted from lining of driving clutch discs and brake pads, from abrasion of tires and asphalt road surfaces, as well as CO_2 emissions. Toxic substances are released into the atmospheric air together with fuel vapors, blow-by gases and exhaust gases during the operation of internal combustion engines. Fuel vapors enter the atmosphere from the elements of the power system. Fuel vapors can be neglected, due to the low volatility of diesel fuel and the tightness of the diesel fuel system when determining the degree of environmental safety of diesel engines. In total, about 8.0% of CH hydrocarbons are emitted into the atmosphere with vapors.

The share of crankcase gases, which are a mixture of unburned hydrocarbons, which enter the crankcase with fuel and oil vapors through leaks in the cylinder-piston group, in the crankcase of a diesel engine does not exceed 0.2-0.3% of the total emission of toxic substances.

Exhaust gases are the main source of toxic emissions and are a mixture of gaseous products of complete and incomplete combustion of fuel, excess air and various trace impurities (gaseous, liquid and solid particles) that comes from the engine cylinders into its exhaust system. Various physicochemical, physical and chemical methods are used to determine the individual components of the exhaust gases. The complexity of evaluating the exhaust gases of automotive diesel engines lies in the variety of harmful substances, as well as in a wide range of changes in their concentrations.

Dangerous accumulators of carcinogenic substances, in particular benzopyrene, are solid particles of soot as a carbon product. Diesel engines emit 10-1000 times tinier soot particles into the atmosphere during the test cycle than gasoline engines. The emission of such particles by weight reaches 1.0% of the fuel consumption. In addition, three unburned carbon atoms per 1000 burned ones give the smoke of the exhaust gases about 30.0%.

The exhaust gas toxicity of diesel engines is largely dependent on the quality of the diesel fuel. With a decrease in the sulfur content in the fuel from 0.31 to 0.03%, the NO_x content in the exhaust gases decreases by 0.2-1.8%; CO_x - by 24.4%; soot - by 13.2-22.6%.

An increase in the cetane number of the fuel from 45 to 51 leads to a decrease in the ignition period, engine severity and maximum combustion pressure. As a result, smoke is reduced at start-up and at medium loads. At increased loads, the cetane number has practically no effect on the smoke, although in this mode there is an intense emission of soot.

The technical condition of the engine has a strong influence on the amount of emissions of harmful substances with exhaust gases. Any malfunction of the elements of the fuel supply system increases the smoke of the exhaust gases in diesel engines, and the development of the engine's motor resource increases the emission of toxic substances (Table 4). So, the opacity can double due to wear of the parts of the cylinder-piston group.

The advance angle of the start of fuel injection has a significant effect on the amount of harmful substances in the exhaust gases of a diesel engine. Reducing the injection angle reduces the formation of nitrogen oxides, however, this increases soot emissions and deteriorates the power and economic parameters of the engine.

Smoke is also increased by factors such as a decrease in the lifting pressure of the nozzle needle and coking of its nozzle holes, clogging of the air filter.

Faults in the transmission and running gear of automotive vehicles increase power consumption,

and, consequently, fuel consumption, which also leads to an increase emissions of harmful substances with engine exhaust gases.

Consequently, most of the factors affecting the environmental performance of diesel engines under operating conditions can be eliminated by timely maintenance and repair.

Table 4. Influence of the technical condition of the engine on emissions of harmful substances with exhaust gases

Types of malfunction	Change in emissions,%				Fuel consumption change,%
	CO	CH	NO_x	smokiness	
Violation of injection pump adjustment	+5-50	+5-25	-25 ...+25	+25-100	+5-25
Violation of the advance angle of the start of fuel injection	+5-50	0-25	-100 ...+100	-25 ...+50	+5-25
Wear of the main engine parts	+50	+100	-25	+100	+15
Malfunction of injectors	+25-50	+50-100	-25	-25 ...+25	+10-20
Increased resistance to air intake and exhaust	+50-100	+50-100	-50	+100	+15
Increased resistance to movement	Increase up to 20.0%				+5-20

Thus, at present, the main problem of the environmental safety of the country's agricultural sector is to reduce the toxicity of exhaust gases from automotive vehicles, as well as to reduce liquid and solid emissions and save natural resources.

Organizational and technological measures provide for the development and implementation of technologies for the cultivation of agricultural crops with a minimum number of passes through the fields of heavy wheeled vehicles (combination of operations) (Parkhomenko et al., 2019).

Cultivation of soils and increasing the content of humus in them are agricultural practices.

Loosening of the arable and subsoil layers with using chisels and subsoilers is applied to loosen the soil. The combination of loosening with the application of organic fertilizers and calcium-containing substances leads to a significant reduction in the negative consequences of machine soil degradation (Zhao & Sharma, 2014).

It is important that only such mechanisms work in the fields, the pressure of the propellers of which on the soil does not exceed 0.1 MPa. For these purposes, it is better to use caterpillar propellers or wheel drives with elastic tires, the pressure of which on the soil is 80-100 and 30-60 kPa, respectively.

Energy-saving technology with minimum tillage provides for the use of the combined machines that perform several process steps in one pass. At the same time, the soil is less compacted and sprayed, and its resistance to erosion increases. In addition, the need for equipment, fuel and lubricants is reduced (by 8.0-27.0%), and the cost of funds and labor is reduced (by 18.0-35.0%) (Qadri, 2019).

Plowing a field with moldboard plows is accompanied by the destruction of the surface layers of the soil. At the same time, the grass cover and sod are destroyed, stubble and other crop residues are plowed, protecting the soil from being blown out and washed away. It is also possible that less fertile soil layers may be turned up on the surface.

Loosening of the soil with flat cutters should be used in areas dominated by wind erosion. This system allows to minimize a soil destruction, ensures rational use of land, increases crop yields in combination with the introduction of grassland crop rotations, correct crop rotation, cutting fields perpendicular to the wind direction, strip placement of crops and other techniques (Volkov & Fomin, 2018).

The total loss of soil with products and on working bodies of agricultural machines, wheels and tracks (especially in wet weather) reaches about 16.0%. Up to 4 t/ha of soil is removed from the most fertile layer with roots in rainy weather. The total annual soil loss is 1.5 billion tons (Rohila et al., 2017). Agrophilic (soil-protecting) running systems are an effective means of combating machine soil degradation.

The use of petroleum products as fuel leads to environmental pollution, including soil.

The main consumers of liquid fuel are tractors, automobiles, and grain harvesters. Exhaust emissions from low-lying tailpipes cause environmental pollution that can be compared to the impact on the atmosphere of large industrial plants (due to the peculiarities of pollution of the surface layer) (Jablonicky et al., 2018; Miloslaw, 2016).

However, diesel engines are inferior to carburetor ones in the content of other components per 1 kg of burned fuel, namely, soot, benzopyrene, aldehydes (in terms of hazard level, carbon monoxide is the least harmful of the generated air pollutants) (Soltani et al., 2016; Gulbis & Smigins, 2005).

Thus, environmentally friendly machines and technologies ensure the safety of the environment, life and health of the population. The key problem of using agricultural machinery is to preserve not only fertility, but also soil resources (Merkisz et al., 2013).

Analysis of the literature showed that to solve the problem, it is necessary:

- to determine targeted actions to solve environmental safety, based on a deep understanding of the processes of formation and cleaning of exhaust gases, spark and flame emission from the exhaust pipes of diesel engines;

- to determine the leading methods of influencing the working processes of catalytic converters, mufflers, flame arresters and use them to solve certain aspects of the problem;

- to perform the mathematical modeling of processes in reactors of catalytic converters and use its results in the formation of complex means of reducing harmful emissions.

The deterioration in the quality of the land is an alarming and intractable phenomenon. Destruction of the fertile soil layer, depletion, waterlogging, pollution, salinization of land, overgrowing with weeds, improper plowing under conditions of wind and water erosion can not only remove land from agricultural use for a long time, but also disrupt long-term ecological ties, change the water balance, lead to destruction fauna, depletion of forests, desertification. These processes can lead on a large scale to partial climate change in the long term. All this necessitates the rational use and special protection of lands provided for the needs of agriculture, as well as those intended and suitable for these purposes.

Determination of the ecological and economic damage to agricultural production requires further research. It is necessary to deeply penetrate into the essence of the relationship between environmental and economic factors, develop technologies that ensure the environmental efficiency of the industry.

Conclusion

Further development of agricultural production, its mechanization and chemicalization of land significantly increase the role of environmental protection in agriculture. Environmental requirements are so significant and fundamentally important. Therefore, it is impossible to talk about the economic efficiency of agricultural production without meeting these requirements. This is of particular importance for agriculture, since this branch of social production is closely related to living and inanimate objects of nature.

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Анотація

Інтенсивна експлуатація сільськогосподарської техніки та її вплив на навколишнє середовище

В.І. Семенцов, В.В. Семенцов, А.П. Палій, А.П. Палій, С.А. Чигрина

Основними видами негативного впливу технологій на природне середовище є газоподібні, тверді та рідкі викиди, викиди тепла, вичерпання ресурсів. В результаті багаторазового переміщення машин по полю відбувається значне ущільнення ґрунту, який поширюється на велику глибину (до 100 см), а машинні колії покривають до 80,0% поля. Щільність ґрунту під впливом важкої техніки збільшується на 20,0-40,0%. Вихлопні гази є основним джерелом токсичних викидів. Вони являють собою суміш газоподібних продуктів повного та неповного згоряння палива, надлишку повітря та різних слідових домішок. Дизельні двигуни надзвичайно токсичні завдяки високому вмісту NO_x, бензолу, альдегідів і сажі, хоча вони мають значно менші викиди CO та CH порівняно з бензиновими двигунами. Окис вуглецю (CO) є лідером серед шкідливих речовин за абсолютними викидами. Його показник становить 10,3 мільйона тонн на рік. Двоокис азоту (NO_2) посідає друге місце з 1,8 млн. т на рік. Вуглеводні (CH) посідають третє місце з 1,5 млн. т на рік. Першість, з точки зору екологічної небезпеки, тримають діоксид азоту (NO_2), свинець (Pb), діоксид сірки (SO_2) і частки сажі. Викиди оксиду сірки (SO_2), монооксиду вуглецю (CO) і бензопірену відіграють значну роль в забрудненні повітря. Тому необхідно в першу чергу забезпечити скорочення викидів цих речовин.

Ключові слова*: довкілля; сільськогосподарська техніка; вплив на навколишнє середовище; викиди; грунт*

Аннотация

Интенсивная эксплуатация сельскохозяйственной техники и ее влияние на окружающую среду

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Основными видами негативного воздействия техники на окружающую среду являются газообразные, твердые и жидкие выбросы, тепловыделение, истощение ресурсов. В результате многократного передвижения машин по полю происходит значительное переуплотнение почвы, которая распространяется на большую глубину (до 100 см), а гусеницы машин покрывают до 80,0% поля. Плотность почвы увеличивается на 20,0-40,0% под воздействием тяжелой техники. Выхлопные газы являются основным источником токсичных выбросов. Они представляют собой смесь газообразных продуктов полного и неполного сгорания топлива, избыточного воздуха и различных микропримесей. Дизельные двигатели чрезвычайно токсичны из-за высокого содержания NO_x, бензола, альдегидов и сажи, хотя они имеют значительно более низкие выбросы CO и CH по сравнению с бензиновыми двигателями. Окись углерода (CO) является лидером среди вредных веществ по абсолютным выбросам. Его показатель составляет 10,3 миллиона тонн в год. На втором месте диоксид азота (NO_2) - 1,8 млн тонн в год. На третьем месте - углеводороды (CH) - 1,5 млн тонн в год. Первенство, с точки зрения экологической опасности, держат диоксид азота (NO_2), свинец (Pb), диоксид серы (SO_2) и частицы сажи. Выбросы оксида серы (SO_2), монооксида углерода (CO) и бензопирена играют значительную роль в загрязнении воздуха. Поэтому необходимо в первую очередь обеспечить сокращение выбросов этих веществ.

Ключевые слова*: окружающая среда; сельскохозяйственная техника; воздействие на окружающую среду; выбросы; почва.*

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