Improving Pit Vehicle Ecology Safety

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Abstract. The article discloses the ways to improve the ecological safety of a pit transport: reducing harmful substance concentrations in exhaust gases, implementation of the ecological certificate of the dumping truck, taking into account the operation of the dumping truck actual work, choosing the best model and comparing ecological characteristics of pit lifters at deep pits.

1. Introduction
Mining industry provides 80% of material and energy resources that the humankind needs. The volume of mineral and fuel resources produced in Russia together with mine stripping works and construction materials reaches billions of tons per year [1].

Mining such volumes needs dozens of thousands of diesel engine equipment units, which consume many millions of tons of diesel fuel. In CIS alone, as the authors assessed, spending diesel fuel at open pits exceeds 2 million tons per year with more than 200 thousand tons per year at Kuzbas pits [2]. It is diesel vehicles that give 95...96% of environment pollution with harmful emissions and exhausted gas. The nature of North is especially vulnerable to it. Pits in Russia and other CIS countries during the current stage of open-pit resource mining provide around 60% of the whole mountain rock to be carried by dumping trucks with the loading capacity of 30...220 tons. Air pollution in pits due to such vehicles necessitates such vehicles to have longer non-operation periods, especially during winter seasons, due to the exhaust gases toxicity, the sanitary and hygienic working conditions for service personnel are worsened sharply. Despite substantial investments, an environmentally friendly diesel can not be created [3-5].

2. Research methodology
Complex assessment of dumping truck ecological characteristics should include dust emission during loading, unloading and transportation of mountain rock, mining enterprise territory pollution with particles of tires, fuel and lubricants during the dumping truck refuelling and repairing works. A serious environmental problem is the disposal of decommissioned car tires, worn out bodies, frames and other metal structures. Due to the large size of these nodes, large areas are cluttered up, which has a negative impact on the environment [6]. Noise, vibration, dust, gases penetrating the vehicle cabin, as well as electrostatic and electromagnetic fields, also harm human health, especially where vehicles with electromechanical transmission are used.

Considering a dumping truck in a complex manner as a multifunctional apparatus, producing energy of different types and having constantly need in resources, is included in the ecological
passport of the dumping truck [7], which allows one to evaluate the ecological characteristics of the dumping truck as the object of the environmental impact. The content, methodological approaches and necessity of implementation were repeatedly reported by the authors at scientific conferences.

The analysis of dumping truck ecological characteristics operated at mining sites should account for, first, all types and sources of environment pollution when operating a vehicle; second, the share of each of those types in total pollution of the environment. Third, a vehicle should be considered as a complex dynamic system with characteristics including environmental ones, change with time as the lifespan goes on. Fourth, there should be the possibility of reducing the emissions by implementing advanced technical and organizational methods, such as exhaust gas neutralization, pit ventilation, transportation schemes improvement etc. [8].

A dumping truck ecology certificate allows monitoring the changes in ecological characteristics of the vehicle throughout its lifespan and upon performing service and capital repair works. Not only exhaust gas emission would be the subject for monitoring; that would additionally include dust levels given by the cargo transported, electrostatic and electromagnetic fields, engine and drives operating noises, oils and lubricants spent [9].

Every year, the dumping truck ecology certificate is filled by the transportation company, allowing maintaining ecology records of the enterprise in a proper manner and comparing the regulatory norms for harmful substances emission with the actual data on various vehicles, optimizing the vehicle fleet structure by the lowest environment pollution criteria.

There are obstacles for introduction of the dumping truck ecology certificate at mining enterprises, such as the missing of the relevant legislation norms and low interest of the enterprise owners in additional expenditures on ecology measures.

BelAZ dumping truck fleet in CIS countries (that is 17250 vehicles) spend around 2.1 million tons of diesel fuel annually. The amount of the exhaust gas would be in proportion to the fuel used [10]. The annual diesel fuel consumption during mining mineral resource in Russia approaches 1.2 million tons. The average specific diesel fuel consumption by dumping trucks at various pits ranges from 100 to 140 g/ton-km. The composition of harmful substances in exhaust gas with the maximum allowed concentration of the components thereof (daily and single time) in mg/m³, their relative aggressiveness, tent. t/t, and approximate emission norms in kg/h are presented in table 1.

| Harmful component | Max. allowed concentration, daily | Max. allowed concentration, single time | Aggressiveness | Dumping truck loading capacity, ton |
|-------------------|----------------------------------|----------------------------------------|----------------|----------------------------------|
|                   |                                  |                                        |                | up to 32 | up to 50 | up to 80 | up to 150 | up to 200 | up to 300 |
| CO₂               | 3                                | 20                                     | 1.0            | 0.4-3.7 | 0.6-0.8 | 1.2-9.7 | 1.3-11.5 | 2.5-20.3 | 3.3-28.5 |
| NOₓ               | 0.05                             | 10                                     | 22.0           | 0.1-3.7 | 0.2-0.8 | 0.4-1.6 | 0.4-1.9 | 0.9-3.4 | 0.8-4.7 |
| C₅H₁₀             | 0.04                             | 2                                      | 41.1           | 0.4-2.5 | 0.6-3.2 | 1.2-6.5 | 1.3-7.7 | 2.5-13.5 | 2.5-19.0 |
| SO₂               | 1.50                             | 100                                    | 3.2            | 0.1-0.8 | 0.2-1.0 | 0.3-2.0 | 0.4-2.4 | 0.7-4.2 | 0.9-5.9 |
| C                 | 0.05                             | 4                                      | 41.5           | 0.1-0.7 | 0.1-0.8 | 0.2-1.6 | 0.2-1.9 | 0.4-3.4 | 0.4-4.7 |

The main methods to reduce harmful emissions:
- using anti-smoke agent;
- installing the exhaust gas neutralization system on dumping trucks;
- fine-tuning vehicle engines to improve fuel burning;
- improving engine and dumping truck design to reduce resistance to motion;
- reducing dumping truck idle run time to use fully the dumping truck operation time;
- using alternative power sources (electricity, gas, spirits, hydrogen).

An efficient way to reduce the most toxic components emission – smoke soot – would be to use special antismoke agents – ECO-1 – and catalyst neutralizers. Burning 1 ton of fuel with ECO-1 agent emits 3.8 kg of soot into the atmosphere (i.e. 0.16 g/m²), with smokiness reduced by 50-60% for main operating modes, by 30-40% - for medium loading operating modes and by 20-30% - for low loading operating modes. The research [11] revealed the efficiency of adding the ECO-1 fuel agent in ratio 0.4% by weight of fuel.

Implementation of the method for reducing exhaust gas volume with changing the dumping truck properties throughout the vehicle lifespan may be possible using the dumping truck ecology certificate.

It may be possible to use the vehicles in a better way, after the transportation company implements a reliable information database for recording and managing dumping truck technical conditions, with computer technology involved. The database information arrays are formed during initial data registration on dumping truck characteristics right at the transportation company. Then it may be used to develop specific measures on vehicles and vehicle parts service works at lower costs and to prove the desirability of arranging and planning the repair works, managing exchange fund spare part stock, maintaining statistical records on failures and repair works, removable parts lifespan, on comparative operation of vehicles - the most efficient by the way and by sites, seasons of the year, etc. Computers may solve the abovementioned tasks very quickly and in a manner that is convenient for the enterprise technical services.

3. Results and discussion
An important condition to reduce the harmful emissions would be to select the optimal dumping truck model. In the Saint-Petersburg Mining University, the authors developed an economical and mathematical model of selecting the optimal type of loading and unloading the transport complex, wherein the effect by a pit vehicle on environment and pollution reduction matters is thoroughly taken into account [11-13].

The model was tested on diamond and apatite mining pits. The following option is that of comparison for pit atmosphere normalization: usage of the fuel agents, natural ventilation (basic), forced ventilation, using the gas protection means for the personnel with exhaust gas neutralization.

For the conditions at the pit “Successful”, the calculated options included using 10 models of dumping trucks produced by national and international manufacturers with loading capacities of 100-150 tons. The discounted cost minimum belongs to the dumping truck “Unit Rig M-150”. The annual weights of harmful substances from the “Unit Rig M-150” dumping truck for various transportation heights are presented in figure 1.

The choice of transportation system for deep pits is important. Ecology factors may play the decisive role in the final selection of such pits. The conducted research allowed selection of the most promising schemes: a vehicle with an elevating machine, a vehicle with a standalone drive; a conveyor (or the system of conveyors) with a transportation angle up to 18 degrees; a conveyor with a transportation angle above 18 degrees. Also, vehicle elevator design parameters and operation indicators during operation in chain with pit dumping trucks were discussed. In such transportation complex configuration, air pollution with exhaust gas takes place. Deeper pits need more dumping trucks to maintain performance, polluting the atmosphere even more and resulting in longer waiting periods and the need to use expensive atmosphere normalization means known. The option of using vehicles only is now common Worldwide and used as the basic one for comparison elevators ecology characteristics. When conveyor transportation is used, the main pollution comes from the dust of the bulk transported, and the amount of it would be insignificant for a steep elevator because the bulk would be covered with a protection band. There would be no need in handling points with steep lifting; therefore, dust appears only during loading/unloading the conveyor band. Figure 2 shows the weight of dust coming from operating the elevators with cargo humidity below 0.5%, wind speed - up
to 2 m/s, and with the dumping truck “Unit Rig M-150” with the involved conveyor band - 0.8 m wide, with pit performance - 20 million tons.

**Figure 1.** The weight of harmful emissions in exhausted gases

**Figure 2.** Annual dust weight from elevators operation
The obtained results numerically prove the optimal selection of the loading/transportation complex with mining works dynamics taken into account, and make it possible to provide project organizations and pit operation services with calculation data on harmful emissions into atmosphere.

![Diagram](image)

**Figure 3.** The recommended areas for rational usage of pit elevators for mining rocks with hardness coefficient \( f = 15 \): 1 – cager with an elevating machine; 2 – skip type with an elevating machine; 3 – conveyor and a steep conveyor; 4 – vehicle (mono-transport); 5 – vehicle elevator with a standalone drive; 6 – the elevator with a locomotive unit.

**4. Conclusion**

Complex research was undertaken on determining the degree of negative influence of diesel mining and transportation complexes on environment. Methodologies were developed to determine the amount of harmful emissions from diesel machines. Requirements were formulated to create a low-toxicity diesel engine vehicle and conveyor elevators of the rock mined. The demand for dumping trucks of mining enterprises of Russia was assessed, and the directions for improving ecological characteristics thereof were defined.

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