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Development of an Effective Method for Preventing Dust Pollution in Stone Quarries Using Petroleum Refinery Wastes

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Abstract

The paper presents a new method for preventing dust pollution in stone quarries using naphthenic wastes of petroleum refineries. The method is based on the use of naphthenate solutions of metals as wetting agents to minimize dust release during stone-cutting process. The studies were carried out in one of the stone quarries of the Absheron peninsula. Initial experiments were conducted by using sodium-naphthenate (RCOONa) solution from alkali wastes of refineries. The results have shown that the use of RCOONa as wetting agent considerably reduces both dust pollution and energy consumption of the used equipment, while increasing the service life of stone-cutting saw. A series of researches were carried out with cupric naphthenate (RCOOCu) to further use the obtained dust-naphthenate mixture in agriculture. The effect of various parameters on the quality of the obtained product was investigated. The investigations have revealed that maximal dust reduction and the good quality of dust-naphthenate mixture were observed with 0.13% solution of RCOOCu at 11˚ - 13˚ angle of slope and 100 - 180 rotation/min. intensity of conveyer.

Keywords

Stone Quarry, Dust Pollution, Refinery, Waste

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1. Introduction

Dust, fly ash, gaseous emissions, grit and other particulates in air are major sources of environment pollution. A huge amount of dust and particulate matter are discharged into atmosphere from industries and manufacturing processes. Many industrial activities (mining, smelting, textiles and production of building materials, etc.) as well as loading and transfer operations are responsible for the pollution of ecosystem by particulate matter. Depending on the material structure large areas can be polluted by solid fractions with various dimensions. The fractions having dimension less than 100 mc are considered to be dust particles. Under influence of gas or air stream the particles produced during technological processes are transformed into suspended condition forming a dispersed dust aerosol system consisting of solid particles and gaseous phase. Dust aerosols in atmosphere could be carried over long distances causing potential hazard for all ecosystem components and in particular for man. Irrespective of their sources, pollution of ambient air by dust results in allergic, dermatologic and respiratory diseases in people. In windy days, dust particles are carried over dozens kilometers after a while accumulate in plants, soils, water basins, buildings and monuments and thus harmfully affect living organisms and other components in the biosphere [1]-[4].

Like many industrialized and urbanized regions in the world, air pollution is characteristic for the Absheron peninsula of Azerbaijan. Despite the fact that the region has long been specialized on the production and processing of its oil and gas resources, the activities of stone quarries and sand pits located in the peninsula play a significant role in the pollution of ecosystem, especially atmosphere air by dust and various solid particles. About 2300 and 1600 ha areas in the peninsula have been degraded by stone quarries and sand pits, respectively [5]. The increase in the number of construction materials' manufacturing enterprises from year to year has resulted in continuous pollution of the environment by their discharges. Today, their negative impact on ecosystem has become a serious concern that requires development and introduction of new environmental friendly technologies.

It is well known that during extraction of mineral deposits considerable part of materials transform into dusty waste. Dusting accelerates wear of the equipment used in these fields and impacts negatively on health of working personnel and the people living in proximity to these raw sources.

The degree of dust pollution in stone quarries is dependent on many variables including the type of equipment, speed of conveyer, size and humidity of rocks, speed and direction of air flow, etc. When dust pollution is not prevented, the concentration of dust can be 2 - 4 times higher than its maximum permissible concentration (MPC) in the work place even under optimal speed and direction of air flow [6].

Minimization of dust release in stone quarries can be achieved through application of new effective technologies. The results of earlier researches showed that irrigation of rocks improve sanitary-hygienic conditions in work places, while reducing energy consumption by 5% - 6% and the cost of cutting instrument maintenance by 2 times [7]-[10]. The use of waste materials for minimizing their adverse effect on the environment is most reasonable way of resolution of ecological problems. Most of industrial waste can be used as raw material in technological processes [11] [12].

Oil industrial wastes are primary pollutants of the environment in the Absheron peninsula. The wastewater produced during oil-gas extraction are saline waters (Cl-Na) with total mineralization of 15 to 140 g/l. Together with I (iodine), Br (bromine) and other chemical components, these waters contain about 927 mg/l naphthenic acids.

A huge amount of naphthenic waste is annually produced in the republic that gives great opportunity for the development of new technologies on the basis of their utilization.

A new method presented in this paper is based on the use of naphthenate containing wastes of refineries for minimization of dust pollution in stone quarries and application of the material produced from the technological process in agriculture. The main directions of researches were:

- Carrying out experiments to study optimal conditions of use of oil industry's naphthenate waste for preventing dust pollution and achieving ecological balance in stone quarries.
- Obtaining and use of cupric naphthenate solution as wetting agent in dust prevention process to improve the quality of the obtained dust-naphthenate mixture for application in agriculture.

2. Materials and Methods

Experiments were carried out in Guzdak quarry situated in the western part of the Absheron peninsula. Stones with dimensions of 30 × 12 × 6 cm, sodium naphthenate-RCOONa and cupric naphthenate-RCOOCu solutions

were used in experiments.

Aqueous waste of oil refineries contain considerable amount of RCOONa. 0.1% - 0.5% solution of RCOONa (with 1.02 - 1.04 g/m^3 density and pH 9) was used as wetting agent during initial studies aimed at preventing dust pollution.

RCOOCu was obtained in laboratory conditions using naphthenic acid of oil industry's waste according to the known method [13]. The naphthenic acid used in the developed technology had the following physico-chemical properties:

1) Density—0. 957 - 0.959 g/cm^3;
2) Index of acidity—220 mg KOH/1g n.a.;
3) Average molecular weight—237;
4) Color—brown.

3. Results and Discussion

The earlier studies of authors [12] have revealed that considerable amount of dust could be reduced by using process water as a wetting agent during development of mineral deposits. The disadvantage of this technology is a low effective dust prevention and premature equipment failure.

Figure 1 presents the results of experiments conducted by using RCOONa solution as wetting agent.

It can be seen from **Figure 1**, the use of surfactant sodium-naphthenate as a wetting agent in stone quarry increases both dust suppression and life service of equipment, while decreasing the time of stone-cutting process that reduces energy consumption.

As it was mentioned above, along with the use of naphthene waste and dust pollution preventing, one of the main objectives of the researches was the obtaining of new product for application in agriculture. It is well known that Cu is one of nutritious elements for plants. It plays an important role in photosynthesis and reproduction stages, improves the quality and taste of fruits and vegetables. The primary advantage of Cu is that it decontaminates infections in living organisms [14].

In order to have this element in dust-naphthenate mixture produced during dust prevention process in stone quarries, RCOOCu solution was used as wetting agent. The RCOOCu solution given to conveyer from a special funnel is mixed with dust produced during cutting of stones. The obtained dust-naphthenate mixture is gathered in a vessel and sent to users for application in agriculture [15].

The studies have shown that the quality of the obtained product as well as minimization of dust pollution in stone quarries are depending on various parameters. In order to determine optimal conditions of the process, the dependence of dust catching with RCOOCu solution on both the angle of conveyer's slope and the concentration of naphthenate solution and also the dependence of dust distribution in RCOOCu solution on the intensity of conveyer rotation have been studied.

The angle of slope of conveyer changed gradually increasing from 1˚ to 27˚. The results of experiments

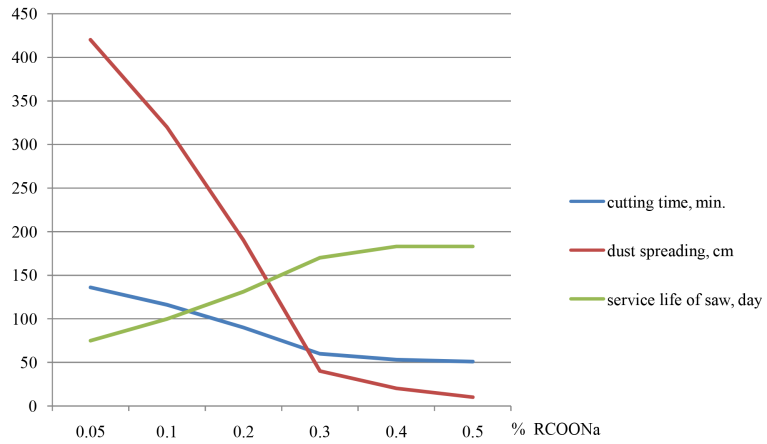

Figure 1. Dependence of parameters of stone-cutting process on the concentration of RCOONa in solution.

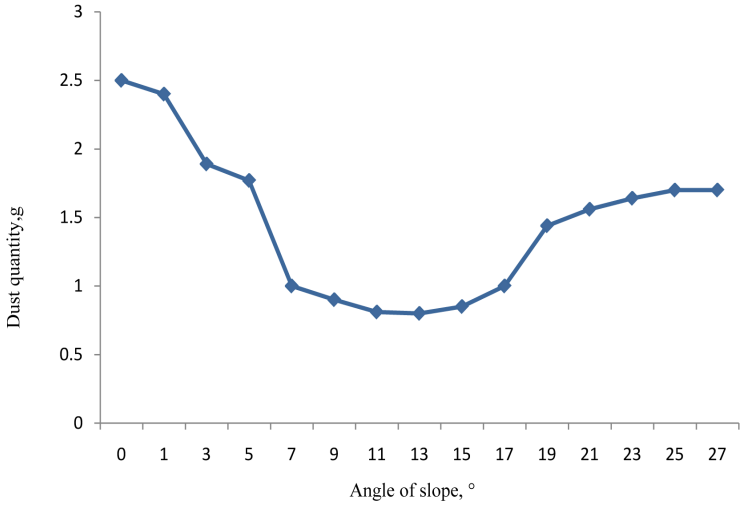

Figure 2. Dependence of dust quantity on the angle of slope of conveyer (concentration of RCOOCu solution—0.13%).

carried out to study the dependence of dust pollution on this parameter are presented in **Figure 2**.

As can be seen from the **Figure 2**, the angle of slope of conveyer plays important role in the interaction between dust and naphthenate solution and the production of a new product. When the angle of slope was 0 no change was observed. With its increase from 1˚ to 13˚ the quantity of dust in ambient air decreases from 2.5 to 0.80 g. The quantity of dust release begun to increase again and was 0.85 g under 15˚ angle of slope of conveyer. The further increase in the angle of slope was resulted in the increase of dust quantity in air. This is explained by the fact that the increase of the angle of slope reduces the time of interaction between dust and naphthenate solution.

Table 1 presents the results derived from the studies of the dependence of dust reducing on RCOOCu concentration in solution. As can be seen from the table, optimal concentrations of RCOOCu in solution for dust minimization is 0.1% - 0.13%. Meanwhile, the increase in RCOOCu concentration from 0.15% to 0.27% exhibited no significant changes in dust quantity reduction in comparison with previous results.

The experiments have revealed that the intensity of conveyer is one of the main factors influencing the quality of final product.

The composition and properties of the obtained new product change depending on equal distribution of dust in naphthenate solution. Therefore, a series of experiments were carried out to study the influence of conveyer intensity on the distribution of dust in solution. The results of studies are presented in **Table 2**.

It can be seen from **Table 2** that when the intensity of conveyer was between 40 - 80 rotation/min. distribution of dust in RCOOCu can not proceed effectively and the obtained product must be dried to have the needed quality. As the intensity of conveyer rises to 120 rotation/min., the dust/RCOOCu ratio achieves an optimal state—90/98 g and there is no need for product drying.

The studies implemented on the development of new dust preventing technology in stone quarries suggest that the intensity of conveyer rotation, the angle of slope of conveyer and concentration of RCOOCu solution are the key factors influencing both dust pollution reducing and the quality of product.

When the angle of slope of conveyer is greater than 13˚, interaction between dust and naphthenate solution can not proceed effectively and the yield of expected product composition is minimal. The experiments showed that the best results during dust prevention in stone quarries were obtained under conveyer's 100 - 180 rotation/min. Intensity under 11˚ - 13˚ angle of slope and 0.13% concentration of naphthenate solution. The dust-naphthenate mixture obtained in this condition can be used for production of mineral complex fertilizer or meliorant in agriculture.

A schematic diagram of the installation used for dust pollution prevention in stone quarry is presented in **Figure 3**.

4. Conclusion

The results of this study show that the use of naphthenate waste of petroleum refineries significantly reduces dust pollution during processing of mineral resources. It has been demonstrated that introduction of the developed

Table 1. Dependence of dust quantity on the concentration of RCOOCu solution (angle of slope of conveyer—11˚).

Cu-naphthenate solution. %	Dust quantity (g)	
	Without naphthenate solution	With naphthenate solution
0.1	12.4	4.8
0.3	12.5	4.7
0.5	11.8	4.9
0.7	12.5	5.6
0.9	12.7	5.7
0.11	12.6	6.1
0.13	13.1	8.8
0.15	14.1	8.9
0.17	12.6	8.6
0.19	12.7	8.6
0.21	12.8	8.7
0.23	12.9	8.6
0.25	13.0	8.7
0.27	12.8	8.5

Table 2. Dependence of dust distribution in RCOOCu solution on the intensity of conveyer (concentration of naphthenate solution—0.13%; angle of slope of conveyer—11˚).

Conveyer intensity (rotation/min)	Dust/RCOOCu ratio (g)
40	50 - 60
60	85 - 96
80	88 - 98
100	89 - 98
120	90 - 98
160	90 - 98
180	90 - 98

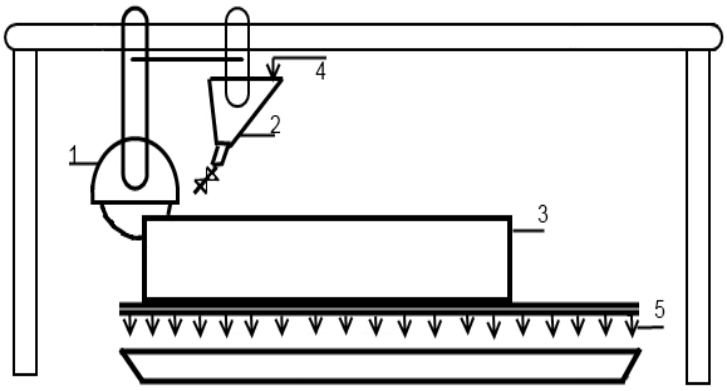

Figure 3. A schematic diagram of installation for dust minimization in stone quarry. 1. Stone-cutting instrument; 2. Funnel for naphthenate solution supply; 3. Stone; 4. Naphthenate solution; 5. Vessel for gathering dust-naphthenate mixture.

new method in stone quarries would lead to minimization of dust quantity in ambient air, while increasing the effectiveness of technological process. There will be no pollution concerning petroleum refineries waste. Because the product obtained during the process is taken out by users for the production of fertilizers. Overall, the proposed method will promote resolution of the problems related to management and utilization of industrial wastes and improve ecological situation throughout the Absheron region.

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