

# Investigation of the process of reducing air pollution when crushing gravel

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**Abstract.** The article is devoted to the problem of ensuring the environmental safety of enterprises for the production of building materials on the basis of modeling the reducing air pollution process. During the analysis of the technological process for the production of crushed stone from gravel, a source of emission that makes the greatest contribution to air pollution, was identified. Physical models of pollution and reduction of air pollution with mineral dust have been developed. The experimental studies' results of dust dispersed composition are presented. It was found that in the process of reducing air pollution, one type of dispersed system is transformed into another due to a forced change in its stability.

## 1 Introduction

Currently, the active development of the construction industry is a key direction of the development strategy in many countries [1-5]. This is evidenced by the increase in the share of the construction sector in the total GDP for the last few years. The search for new building materials and the introduction of innovative construction technologies must meet strict environmental safety standards. Therefore, for those countries where the construction industry development does not yet correspond to world indicators, Technosphere safety remains under threat [6-7]. This is due to the fact that almost any technological process in the construction industry is accompanied by the release of a significant number of polluting substances, 80% of which is dust aerosol [8-9].

According to analytical data, crushing and screening plants and transfer units are the main sources of dust at enterprises for the building materials production [10-11]. In the vicinity of such technological equipment, the concentration of dust in the air of the working area exceeds the maximum permissible norms by 15-20 times. Taking into account the study results of the combating dust issue at enterprises for the production of building materials, it can be concluded that the task of ensuring environmental safety has been very relevant for many years [12-13]. In this regard, for further consideration we have chosen the process of making crushed stone from gravel, namely the stage of crushing, during the implementation of which the maximum amount of dust aerosol enters the air [14]. The main objectives of the study were: a detailed analysis of the technology for the crushed stone production, modeling the process of air pollution by the emissions of crushing equipment,

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the experimental studies of dust and the development of a model for reducing air pollution, which gives a possibility to select the optimal methods and means of combating dust in the future.

## 2 Materials and Methods

The work used the research methods based on the theory of systems modeling, analysis of the known scientific and practical results, and also applied the main provisions of the dispersed systems theory.

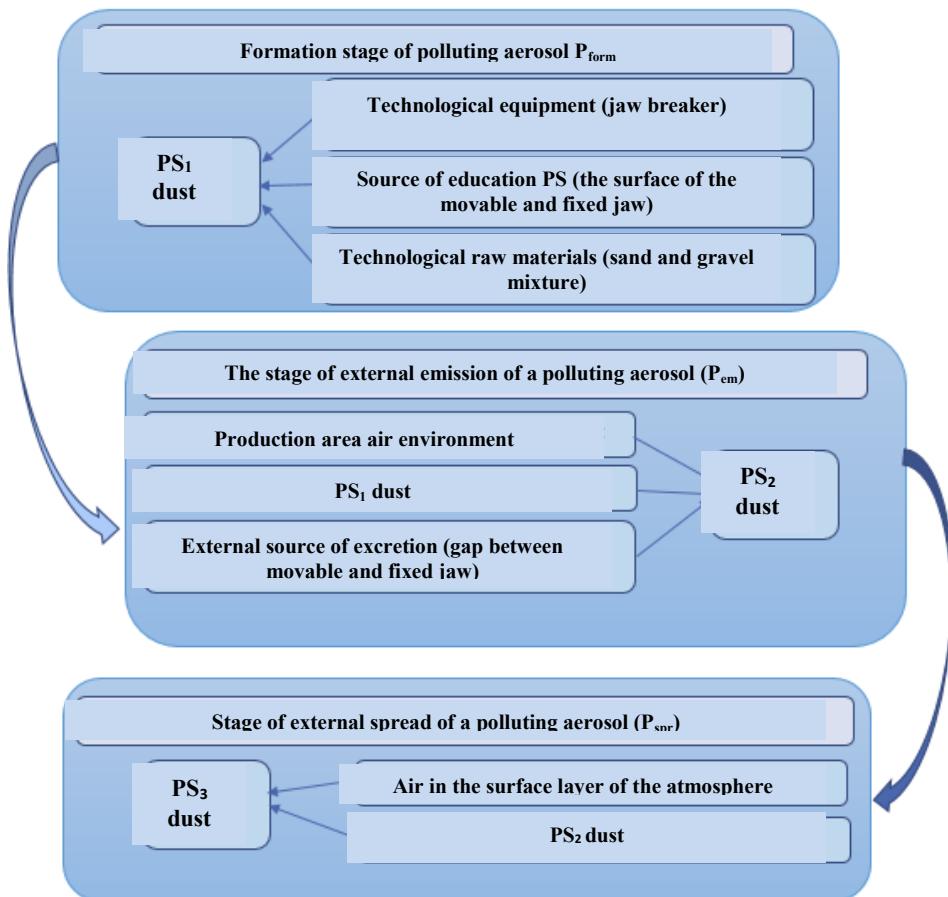
## 3 Results

The analysis of the crushed stone production technology at one of the enterprises showed that the process consists of the following stages: dosing, screening, crushing, screening, crushing, screening. Moreover, at the stage of crushing the raw material, the greatest emission of dust occurs, falling into the air of the working area at the industrial site, and then into the air of the atmosphere surface layer.

We have analyzed the objects involved in the process of air pollution during the crushing of raw materials. The main ones are technological equipment (jaw crusher), technological raw materials (sand and gravel mixture), the air environment of an industrial site and polluting substances (mineral dust). At the same time, polluting substances undergo qualitative and quantitative changes in the parameters of properties throughout the entire process of air pollution. Proceeding from this, the process of pollution itself is presented by us as a sequence of stages of interaction of polluting substances with other objects of the process. The essence of air pollution process is demonstrated by the physical model developed by us (Fig. 1). In this model, the process of air pollution is represented by us in three successive stages: formation, external release and external spread of the polluting substance (PS). Different objects are involved in each of the identified stages. So, at the stage of the polluting substances formation, dust particles are separated from the bulk of technological raw materials due to its interaction with technological equipment. The resulting dust particles have characteristic parameters of properties for this stage and, therefore, are indicated in the PS<sub>1</sub> model.

Since the technological process of crushing takes place, as a rule, outside the premises, the second stage of air pollution process is called the external release of polluting aerosol. A feature of this stage is the transition of dust particles into a suspended state under the air flows influence in the dust formation zone. As a result, a disperse system is formed - a dust aerosol, including a gaseous dispersed medium and a solid dispersed phase. The dust aerosol particles are located at a distance from each other, significantly exceeding the intermolecular forces action radius. Dust particles released from the bulk of the raw material at this stage have their own parameters of properties and are indicated in the model PS<sub>2</sub>.

The third stage of the pollution process is characterized by the interaction of dust aerosol released into the air of the production site with the air of the surface layer of the atmosphere, further separation of particles from each other and represents the external spread of the polluting aerosol PS<sub>3</sub>.



**Fig.1.** Physical model of the process of air pollution during crushing of gravel

Thus, the essence of the physical model can be characterized by the probability of the air pollution process implementation ( $P_p$ ), which is a set of probabilities of sequential events: the probabilities of the polluting substance formation ( $P_{form}$ ), the likelihood of a polluting substance external release ( $P_{em}$ ), the likelihood of the polluting substance external spread ( $P_{spr}$ ).

The identified main stages of the air pollution process during gravel crushing made it possible to determine the most significant property of the polluting substance, the parameters of which determine the further process of reducing pollution. This property includes the dispersed composition of particles, determined by us in the course of experimental studies.

For experimental studies, a sieve analysis of the particle size distribution was selected by sieving through sieves with different mesh sizes. The experimental studies' results are presented in Table 1.

**Table 1.** The experimental studies' results

Sieve mesh size, microns	Boundary particle sizes of fractions, microns	Fraction mass		Full balance, %
		in grams	in %	

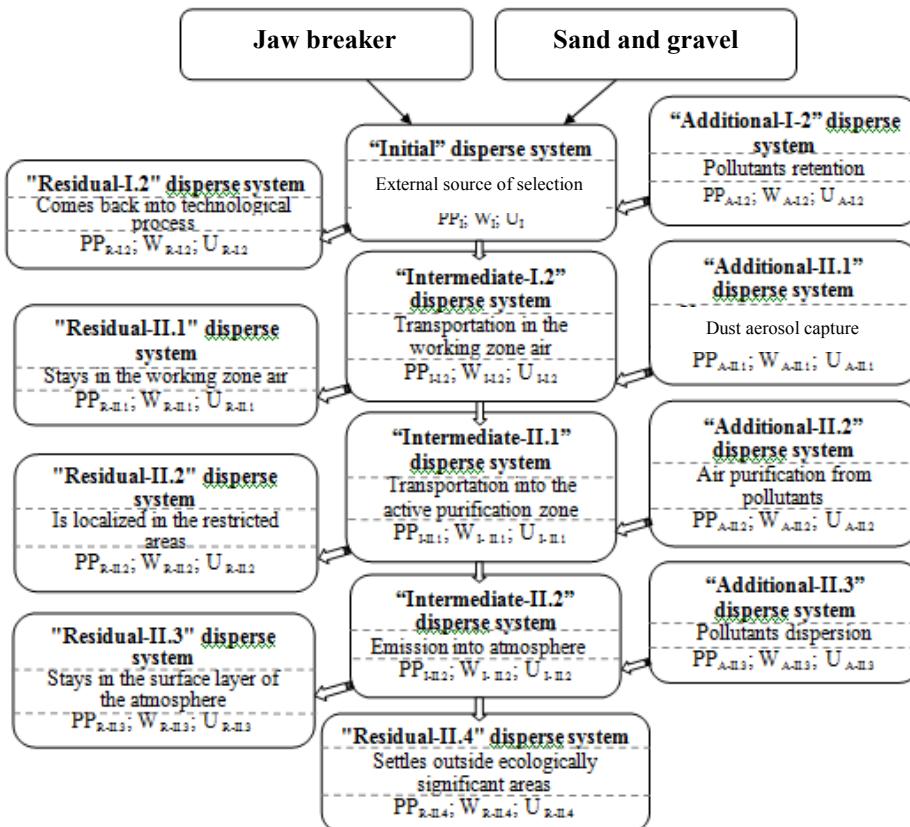
140	140	0.76	1.52	1.52
100	140-100	1.56	3.12	4.64
70	100-70	1.02	2.04	6.68
60	70-60	1.63	3.26	9.94
50	60-50	3.33	6.66	16.6
40	50-40	2.38	4.76	21.36
30	40-30	18.5	37.0	58.36
20	30-20	11.64	23.28	81.64
10	20-10	6.73	13.46	95.10
base plate	10-0	2.45	4.90	100
Total:		50	100	

Analysis of the experimental studies' results showed that the main share of mineral dust particles falls on fractions of 10-40 microns, which corresponds to medium-dispersed dust.

On the basis of the obtained theoretical and experimental results, we investigated the process of reducing air pollution with dust during gravel crushing. For this, we have developed a physical model for reducing air pollution, in which the successive stages are identified: retention, capture, purification and dispersion of polluting substances (Fig. 2). At each of the stages, it is assumed that an external impact on the polluting aerosol is provided with the help of additional dispersed systems. In this case, a part of dust aerosol that has fallen under the influence of an additional dispersed system is directed to a pre-selected area and is called an intermediate dispersed system.

A detailed analysis of each of the air pollution reduction process stages revealed the following. In the process of the feedstock interaction with the working body of the technological equipment, mineral dust is formed, which is the "initial" dispersed system, which has the parameters of properties  $PP_I$ , sustainability  $U_I$ , energy parameters  $W_I$ . Since it is impossible to prevent the dust formation process, the initial stage of the air pollution reducing process will be retention with the help of an additional dispersed system "Additional-I-2", which has its own parameters of properties  $PP_{A-I.2}$ , energy parameters  $W_{A-I.2}$  and sustainability  $U_{A-I.2}$ . The purpose of the polluting substance retention stage is to prevent the dust emission process from the total volume of raw materials. This function can be performed by a closed-type aspiration shelter. As a result of the effect of the additional dispersed system "Additional-I-2" on the original "Initial", an intermediate disperse system "Intermediate-I.2" and a residual disperse system "Residual-I.2" are formed. The intermediate dispersed system begins transportation through the aspiration system, and the residual dispersed system returns to the technological process.

The next stage - the capture of dust aerosol is carried out by an additional dispersed system "Additional-II.1" with the specified parameters of properties  $PP_{A-II.1}$ , persistence  $U_{A-II.1}$  and the energy parameters  $W_{A-II.1}$ . In this case, two dispersed systems are formed: intermediate "Intermediate-II.1" and residual "Residual-II.2". The intermediate dispersed system at the capture stage contains the maximum number of particles of the dispersed phase, which are injected into the active cleaning zone. Each of the dispersed systems has its own characteristics of properties, stability and energy parameters.



**Fig. 2.** Physical model of the air pollution reducing process when crushing gravel

In the process of cleaning the intermediate dispersed system "Intermediate-II.1" is influenced by the additional dispersed system "Additional-II.2" (cleaning element). In this case, two systems are also formed: the intermediate "Intermediate-II.2" and the residual "Residual-II.3". The intermediate dispersed system is practically purified air with a residual concentration of polluting aerosol, which is directed into the atmospheric air through a forced dispersion system (if required). Residual disperse system "Residual-II.3" with increased stability is a coherent disperse system sent for disposal from the purification system.

The final step in the process of reducing air pollution from gravel crushing is the polluting substances' dispersion. This step is optional and is carried out in case of insufficient cleaning. As a result of the dispersion process, two residual dispersed systems "Residual-II.3" and "Residual-II.4" are formed. The essence of the dust aerosol forced dispersion process lies in the impact on the air flow with residual pollution by the external additional dispersed system "Additional-II.3" prepared in advance according to the parameters. In this case, the residual "Residual-II.3" dispersed system in the dispersion process remains in the atmosphere surface layer, and the residual "Residual-II.4" settles outside the ecologically significant zones.

Thus, with the successive impact on the initial, intermediate and residual disperse systems by the external additional dispersed systems in accordance with the laws of energy mass conservation, the interacting systems are transformed. This transformation consists in the fact that the newly formed disperse systems differ in the properties parameters (PP), energy parameters (W) and stability (U) from interacting.

## 4 Discussion

The analysis of air pollution reducing process during gravel crushing made it possible to establish the following:

- in the process of reducing air pollution, one type of dispersed system transforms into another due to a forced change in its stability;
- in order to implement the next stage, it is necessary to determine the effectiveness of the previous stage;
- it is most difficult to control the parameters of the polluting substance in the aerosol state.

## 5 Conclusion

Thus, we can conclude that the process of reducing air pollution when crushing gravel can be divided into stages. Each stage can be controlled by an additional dispersed system capable of changing the polluting aerosol stability. The stability of the polluting aerosol increases continuously from stage to stage. Therefore, the earlier special protective measures are implemented in the pollution process, the more cost-effective their implementation will be. The results obtained in the course of the study are the scientific justification for the choice of promising directions for reducing air pollution by dust aerosol when crushing gravel. Environmentally effective measures implemented in the production of building materials will significantly improve the environmental safety of urban areas near such enterprises.

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