BIOSCIENCES BIOTECHNOLOGY RESEARCH ASIA, December 2014. Vol. **11**(3), 1615-1620

Development of Physical and Energy Concept for Assessment and Selection of Technologies for Treatment of Emissions from Urban Environment Objects

Vadim Igorevich Bespalov, Oksana Sergeevna Gurova, Natalia Sergeevna Samarskaya, Ekaterina Petrovna Lysova and Alexandra Nicolaevna Mishchenko

Rostov State University of Civil Engineering (RGSU),
Rostov-on-Don, Sotsialisticheskaya, 162, 344022.

doi: http://dx.doi.org/10.13005/bbra/1560

(Received: 30 October 2014; accepted: 05 December 2014)

In the article the authors propose a scientific physical and energy concept for solving the problem of assessment and selection of eco- and energy-efficient methods and means for the treatment of waste and exhaust gases from the main sources of urban air pollution. Development of the concept involved the stages of survey of toxic substances as disperse systems, physical models building of the processes of urban air pollution and pollution reduction. At the final stage of the research, a technique was developed for selection of eco- and energy-efficient methods and means for treatment of waste and exhaust gases from main sources of urban air pollution and its practical approbation.

Keywords: Treatment of waste and exhaust gases, Eco- and energy-efficiency of methods and means for emissions treatment, toxic components.

In modern conditions of urbanization with the current structure of functional zoning of cities there is a tendency to development of residential areas, which is reflected first of all by the growth of office and business centers, commercial and public organizations, as well as other institutions in the nonproduction sphere (Kazuhiro Yuki,2007, Marc Antrop,2004, Paul Waley,2009, Qingsong Wang *et al*.,2013, Vavilova, 2009). In contrast to such institutions, industrial enterprises are concentrated close to city outskirts or a few kilometers away from the city in the industrial zone specially arranged for them. Only construction industry enterprises, as well as construction sites, remain in urban areas. This is due to the reduction in transportation costs, decrease in production costs, the availability of additional jobs which are filled with urban residents (Ann T.W. Yu *et al*.,2014, Sukkoo Kim, 2005).

All zones of residential areas (zones of housing, public and commercial buildings and structures, zones of construction objects and construction industry enterprises) need in providing with different types of energy and vital resources supplied by life-support systems (systems of heat and gas, power, water supply, communication systems and transport) (Boyce, D.E., 1986, Samira Fazlollahi *et al*.,2014). A distinctive feature of the above listed systems is that, on the one hand (technological aspect), they

* To whom all correspondence should be addressed.
E-mail: nat-samars@yandex.ru

should be close to the consumers, that is on the urban development territory, and on the other hand (environmental aspect) they have the most adverse impact on the condition of air environment in cities, in particular thermal power enterprises and transport (Il'chenko I.A.,2009, Public Report ,2014, Moomaw W.R.,1996, Grantz D.A.,2003).
This is the ecological paradox of life-support systems operating in populated areas (Brown L.R.,2002). Thus, in terms of air pollution on the urban development areas can be identified life-support systems (primarily, thermal power enterprises and transport) and construction industry objects (enterprises for the production of building materials and construction objects themselves) (Mcdonald.K ,2012).

The most significant toxic components in terms of contribution during combustion of different types of fuel in thermal power enterprises are sulphur dioxide, carbon monoxide, nitrogen oxides, carbon black, vanadium oxide (V_2O_5) and benzo (a) pyrene (Bespalov V.I.,2014).

From construction industry enterprises to urban air environment come emissions of abrasive dust, dust SiO_2 with various percentage (less than 20%, 20-70%, more than 70%), wood dust, combustion products, welding aerosol, oxides of manganese, iron, etc. (Bespalov V.I.,2014).

Exhaust gases from urban transport contain carbon dioxide, carbon black, hydrocarbons, oxides of carbon, sulphur and nitrogen (Y. F. Zhu *et al*., 2002). Herewith, as a rule, total amount of toxic substances emissions by motor transport is about 70% of all modes of transport, or about 40% of the total anthropogenic air pollution in cities (Marshall J.D.,2003, Maricq M.M., 2013).

Currently, a variety of technologies is used for treatment of toxic exhaust gases emissions from construction industry objects and life-support systems of cities around the world. The choice of most of these technologies is carried out using as a final criterion efficiency of the implementation of the process as a whole or its individual stages. However, the development of modern technologies for treatment of urban air pollution allows to offer the number of different engineering and urban planning decisions in order to achieve the same value of the required efficiency, which indicates insufficiency of using only eco-efficiency indicator as the optimization criterion.

Thus, the aim of our research was to develop a scientific physical and energy concept, the essence of which is to examine the toxic pollutants as a dispersed system with certain properties, consisting of the disperse phase (solid, liquid, gas) and gaseous dispersion medium (air). To achieve the goal, we solved the following problems:

a) examined the toxic substances as disperse systems and systematized parameters of their properties, energy parameters and stability that determine the behavior and state of air-polluting substances.
b) built physical models of the process of urban air pollution by toxic components and the process of reducing urban air pollution.
c) made the mathematical description of eco- and energy efficiency as the resulting criteria for selecting the technology of emissions treatment;
d) developed the technique of the selection of most eco- and energy efficient technologies for the treatment of waste and exhaust gases emissions from construction industry objects and life-support systems of cities;
e) made practical approbation of the proposed physical-energy concept for the various emissions of waste and exhaust gases in urban environments.

Methodology

Research methods are based on the fundamentals of the theory of disperse systems, system analysis and system modeling, analytical generalization of the known scientific and practical results, methods of probability theory and mathematical statistics, expert assessments, and other methods.

DISCUSSION

The physical-energy concept proposed by the authors includes consideration of the two interrelated processes: air pollution by toxic components of waste and exhaust gases from life-support systems and the construction industry objects, and the reduction of urban air pollution. The process of air pollution includes the main stages (formation, emission, distribution), on sequential going through which raw materials

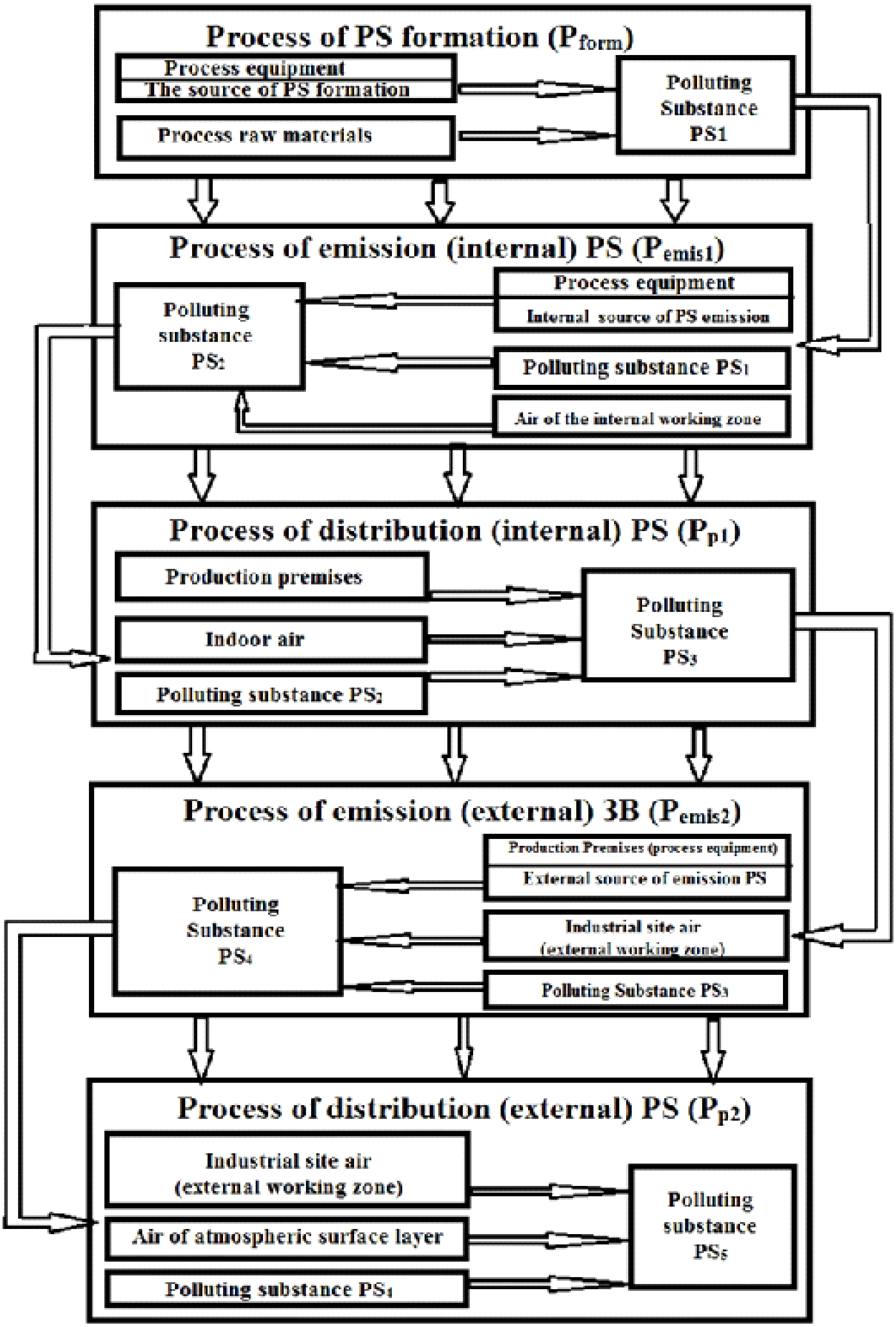

Fig. 1. Physical model of the process of air pollution

transform in polluting substance (PS) that at each subsequent stage undergoes quantitative and qualitative changes. We developed the structure of the physical model of air pollution which is based on taking into account the peculiarities of the interaction of the basic physical objects involved in the process of air pollution: process equipment, process raw materials, production premises, the air of the working zone and the atmospheric surface layer (Figure 1).

The essence of the physical model of the process of air pollution taking into account the feasibility of the dependent sequence of events is expressed by the formula:

$$P_{pol} = P_{form} - P_{emis(1)} - P_{emis(2)} - P_{ditr(1)} - P_{distr(2)}' \quad ...(1)$$

where $P_{pol.}$ - the probability of the process of air pollution; $P_{form.}$ - the probability of the process of pollutants formation; $P_{emis.(1)}$, $P_{emis.(2)}$ - respectively, the probabilities of the processes of internal and external emission of pollutants on the condition of the implementation of the process of their formation; $P_{distr.(1)}$, $P_{distr.(2)}$ – respectively, the probability of the processes of internal and external distribution of pollutants (polluting aerosol) in the air environment in case of the implementation of the processes of their emission.

The physical model of pollution developed by the authors forms the basis of a physical model of the process of reduction of urban air pollution, the essence of which lies in a complex of consistently and purposefully implemented processes at each stage of contamination (Figure 2).

Mathematically, the physical model of the reduction of air pollution, taking into account the feasibility of the dependent consecutive events, can be expressed by the following formula:

$$P_{rp}=1-[1-(1-P_{ib})(1-P_{d})]\times[1-P_{c}(1-P_{cl})(1-P_{dis})], \quad ...(2)$$

characterizing the probability of the process of reduction of environmental pollution (P_{rp}) as a complex of probabilities of physical processes of contamination reduction of initial raw materials (process equipment), including binding (P_{ib}) and the detention of an aerosol (P_{d}), as well as reducing air pollution, which includes capturing (P_{c}), cleaning (P_{cl}) and dispersion (P_{dis}). In the process of reducing environmental pollution, at some stage one or another object is included. Here, there is a certain correspondence of the certain steps of the process of pollution reduction to the stages in the process of environmental pollution:

a) the binding process is organized at the stage of pollutants formation;
b) the process of aerosol detention - at the stage of its emission;
c) the processes of collecting, clearing and dispersing - at the stage of aerosol distribution.

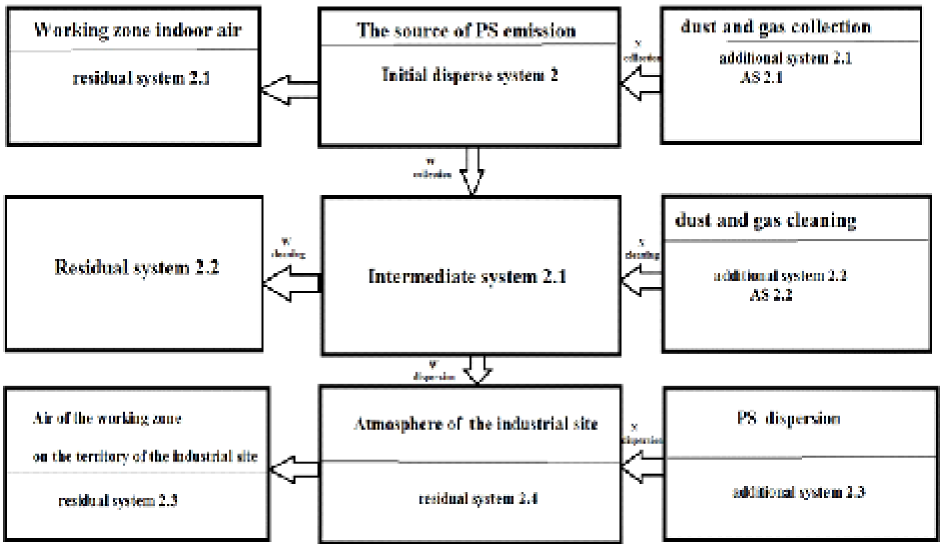

Fig. 2. The physical model of the process of reduction of air pollution

In this, the process of reducing pollution, which includes two main cycles, is considered as a complex of sequentially directed impact on "initial" and "intermediate" systems by "additional" disperse systems. The main purpose of each step in the process of pollution reduction is to reduce the concentration of the disperse phase in the "initial", "intermediate" and "residual-3" disperse systems.

Analysis of the peculiarities of the redistribution of the energy parameters of disperse systems involved and generated in the processes of collecting, clearing and dispersing allows to obtain for them the parametric dependence of the positive (N_c, N_{cl}, N_{dis}) and consumed (W_c, W_{cl}, W_{dis}) energies, as well as to determine the relationship of these forms of energy with the stability of the aerosol.

Therefore, to evaluate the results of each stage and the whole process of air pollution reduction in addition to the ecological efficiency $_{ef}$, we proposed to use the criterion for evaluating the energy efficiency of the process - energy intensity index $^{-}$.

Under energy intensity index $^{-}$, %, we understand the ratio of the specific energy W (watts), consumed for the capturing, collection and removal of pollutant particles from the volume of air, to the specific energy N (W), consumed for creating directed external influences on the contaminant (i.e. "additional" disperse systems – airflows, foam, steam, dispersed liquid, etc.):

$$E^{э} = \frac{W}{N}\cdot 100 \qquad ...(3)$$

In order to obtain the parametric dependence of energy intensity index of each stage in the process of reduction of environmental pollution, it is necessary in all cases to know the mechanisms of interaction and the characteristic energy parameters of the "initial" and "additional" disperse systems. In this, the total dependence for energy intensity index takes the form:

$$E^{э} = \frac{\sum_{i=1}^{n} W_i}{\sum_{i=1}^{n} N_i}\cdot 100 \qquad ...(4)$$

where i - corresponding physical mechanism of interaction between the "initial" system and "additional" ones on the given stage of the process of environmental pollution reduction.

A physical model of the known ways of reducing air pollution at the level of each of its elements being developed, it is possible to construct a generalized model of this process with the step-by-step determination of resulting parameters of efficiency and energy intensity index of corresponding processes for each element of the system.

At the analysis of the model of some methods, there is the possibility, firstly, to improve the technical means of realization of each method in order to enhance its ecological efficiency $_{ef}$ and energy efficiency $^{-}$, secondly, in specific territorial conditions for any source of urban air pollution, you can choose the method of implementation of each element of the system of reducing air pollution, calculate the optimal operating parameters and select (or develop) the most appropriate engineering and urban planning solutions, thus forming the most eco-efficient and cost-effective engineering system.

Proposed by the authors method of choosing the most eco-efficient and energy-efficient systems of reducing urban air pollution includes the following stages:

a) collecting information on each functional element of reducing air pollution possible for implementation in specific urban development conditions;

b) for each functional element, formation of groups of methods, techniques and types of the process of reducing air pollution, taking into account the characteristics of the process equipment;

c) selection of the most suitable groups of methods, techniques and types realization of the process of reducing air pollution in terms of compliance with the requirements of the technological characteristics of the objects of life-support systems and construction industry, as well as site characteristics of the built-up area.

d) within each functional element, identification of the resulting parameters of the process and formation of eco-efficient and energy-efficient systems of reducing urban air pollution based on the selection of optimal values of these parameters able to ensure the maximum allowable concentration.

CONCLUSION

It is this technique, in our opinion, that may be the basis for further research, as it accounts for the most complete collection of different properties of both pollutants and components of urban environment.

The main advantage of the proposed method, unlike all the others, is that the choice of methods and means of reducing urban air pollution can be made at the design stage of the object.

The results of our research have been tested in practice to select the most eco-efficient and energy cost-effective technology for the treatment of waste and exhaust gases from construction industry objects and life-support systems of the city. For example, the proposed method has been applied to the city of Rostov-on-Don. As the building industry enterprises the brick factory was chosen, and as the most significant equipment - a drying drum for which the technique has been implemented and a system of dust control has been established with environmental efficiency of 99.5%. In this, aerodynamic method of treatment with vortex flow has been selected and implemented using a spherical cyclone unit.

REFERENCES

1. Ann T.W. Yu, Yuzhe Wu, Bibo Zheng, Xiaoling Zhang, Liyin Shen., Identifying risk factors of urban-rural conflict inurbanization: A case of China. *Habitat International*, 2014; **44**:177-185.
2. Bespalov VI, Gurova OS, Samarskaya NS, Yudina NV, Gevorkyants IN., Research of the process of urban air pollution by construction industry enterprises. *Collection of scientific works SWorld*.- 2014; **1** (3): 15-20.
3. Bespalov VI, Lysova EP, Paramonova ON, Ganicheva LZ, Pirozhnikova TL, Mishchenko AN., Impact analysis and the development of a physical model of the process of air pollution for the enterprises of thermal power complex. *Collection of scientific works SWorld*.-2014; **1**(3): 3-10.
4. Boyce, D.E. , Integration of supply and demand models in transportation and location: problem formulations and research questions, *Environment and Planning A*, 1986; **18**: 485-489.
5. Brown L.R., The eco-economic revolution. *Futurist*. 2002; **36**(2): 23-32.
6. Grantz D.A., Garner J.H.B., Johnson D.W., Ecological effects of particulate matter. *Environment International*. 2003; **29**(2-3): 213-239.
7. Il'chenko I.A., Research of primary and secondary air pollution of industrial cities and the ways to reduce it. *News of Higher Educational Institutions. The North Caucasus region*. Series: *Natural Sciences*. 2009; **6**. 79-83.
8. Kazuhiro Yuki Maricq M.M., Monitoring motor vehicle pm emissions: an evaluatio of three portable low-cost aerosol instruments. *Aerosol Science and Technology*. 2013; **47**(5): 564-573.
9. Mcdonald K., 11 - Air pollution in theurban atmosphere: sources and consequences. *Metropolitan Sustainability*, 2012; 231-259.
10. Marc Antrop., Landscape change and theurbanization process in Europe. *Landscape and Urban Planning*, 2004; **67**(1-4): 9-26.
11. Marshall J.D., Riley W.J., McKone T.E., Nazaroff W.W., Intake fraction of primary pollutants: motor vehicle emissions in the south coast air basin. *Atmospheric Environment*. 2003; **37**(24): 3455-3468.
12. Moomaw W.R., Industrial emissions of greenhouse gases *Energy Policy*. 1996; **24**(10-11): 951-968.
13. Paul Waley., Distinctive patterns of industrial urbanisation in modern Tokyo. *Journal of Historical Geography*, 2009; **35**(3): 405-427.
14. Public Report., On the state and protection of the environment in the Russian Federation in 2012. Moscow, January 15, 2014.
15. Qingsong Wang, Xueliang Yuan, Jian Zhang, Ruimin Mu, Huichun Yang, Chunyuan Ma., Key evaluation framework for the impacts ofurbanization on air environment – A case study. *Ecological Indicators*, 2013; **24**: 266-272.
16. Samira Fazlollahi, Luc Girardin, François Maréchal., ClusteringUrban Areas for Optimizing the Design and the Operation of District EnergySystems. *Computer Aided Chemical Engineering*, 2014; **33**: 1291-1296.
17. Sukko Kim., Industrialization andurbanization: Did the steam engine contribute to the growth of cities in the United States? *Explorations in Economic History*, 2005; **42**(4): 586-598.
18. Vavilova T.Y., Background of regulation of planning and development of multifunctional industrial and residential areas. *Privolzhsky Scientific Journal*. 2009; **4**: 100-105.
19. Zhu Y. F., Hinds W. C., Kim S., Sioutas C., J., *Air Waste Manage. Assoc*., 2002; 1032-1042.