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ASSESSMENT OF OXYGEN CONCENTRATION REDUCTION NEAR THE HIGHWAY - IMPORTANCE FOR HEALTH AND QUALITY OF LIFE

Abstract:*Oxygen content is one of the most important indices of the atmospheric air quality, on which the health and working capacity of the population depend. Many researchers do not consider a constant decrease in oxygen concentration to be dangerous for human health. Nevertheless, a local drop in the oxygen content in the air near the highways can cause negative consequences for human health. Undoubtedly, the constant growth of motorization in Tashkent leads to intensive oxygen absorption from the urban atmosphere to realize the fuel combustion processes. The purpose of this study is to assess the decrease in oxygen concentration in the air of Tashkent city near the highways due to the motor transport traffic. As was experimentally determined, a decrease in the oxygen concentration in the atmospheric air was observed near the highways; and the intensity of the decrease was related to the intensity of vehicle traffic. During rush hours, oxygen concentration near the highways could reach the values that are hazardous to humans, up to 19.6 - 19.5% O2. A modified Kitsenko equation was proposed to perform an express assessment of the oxygen concentration; the authors have introduced the coefficients of irregularity of movement into this equation. The proposed method will make it possible to assess the oxygen content by an indirect indicator (traffic intensity) and timely inform the population about the air quality.*

Keywords: *Urban Air; Traffic Flows; Oxygen Concentration.*

1. Introduction

The oxygen content in the ambient air, necessary for breathing, is a key factor in determining a person's well-being. The mass concentration of oxygen in the surface air depends on the temperature, pressure, and humidity of the air; in natural conditions, it is described by the classical formulas of thermodynamics. Over the past millennia, natural sources and flow rate of oxygen have maintained the O2 percentage in the Earth's atmosphere at the level of 20.95%, which today is a "world constant" (Ginzburg et al., 2014, Zaporozhets et al., 2018). However, the development of industry, agriculture, the burning of fossil fuels, vehicle traffic, and other anthropogenic processes have changed the air oxygen content in specific places, especially in the atmosphere of large cities,

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where more than half of the world's population lives.

The population of cities breathes the air already "used" by industrial enterprises and vehicles. Therefore, such air with a low O2 content can be considered as waste air, and called "depleted air". Depleted air can be compared to mine dumps: they contain the raw materials needed in industry but in a low concentration.

A decrease in the concentration of oxygen in urban air poses a threat to human health. Therefore, in order to take any protective measures, it is necessary, first of all, to develop tools for assessing the degree of decrease in oxygen concentration under the influence of anthropogenic factors. In large cities, such as the capital of Uzbekistan, Tashkent, road transport is the main consumer of oxygen.

In this regard, the purpose of our study is to determine the effect of road transport on O2 content in urban air, to develop a method for calculating O2 concentration changes, and to assess the economic damage caused by a decrease in O2 concentration.

2. Literature review

The danger of reducing the amount of oxygen in the atmosphere is discussed by many authors, although there is no consensus on this issue.

According to the results of research conducted by the All-Russian Research Institute for the Electrification of Agriculture (Chirkov, 2015), the total annual loss of atmospheric oxygen on the planet, as a result of the combustion of fuels from fossil raw materials, exceeds 7.5x107 tons.

Jianping Huang argues that human activities have irreversibly depleted O2 in the atmosphere. At the current rate of combustion of carbon fuels, by 2100, the O2 concentration will decrease from the current level of 20.946% to 20.825% (Jianping Huang et al., 2018).

Keeling (1988, 2013) indicates that there is no direct threat to human health since the combustion of all hydrocarbon fuel reserves will lead to the loss of only 3.3% of atmospheric oxygen.

The Scripps program also shows a decline in oxygen levels worldwide due to the combustion of fossil fuels: an average of 19 O2 molecules out of every million are lost annually. It is believed that such changes cannot affect human health (https://scrippso2.ucsd.edu/).

However, neither training courses on ecology, nor normative documents in the sphere of environmental protection consider the problem of oxygen reduction in the air of the cities.

Thus, in the opinion of a large number of researchers, the threat of a decrease in the concentration of oxygen in the atmosphere is real.

It is widely known that a lack of oxygen in the air causes hypoxia in humans - a low oxygen content in the body. At present, insufficient attention is paid to the state of the atmosphere in large cities, which follows from the fact that there is no item in reducing the O2 content in the existing recommendations and methods to assess environmental pollution (EEA Report, 2018). At the same time, oxygen consumption, as a result of fuel combustion, is constantly increasing. In particular, over the last 10 years, in Asian countries, there is an increase in oxygen consumption by 28% (Zamolodchikov, 2006, Zamolodchikov, 2020).

We consider the impact of the O2 concentration decrease on human health.

In medicine, classification of weather types was developed according to their effect on human well-being, the oxygen concentration is one of them. So, there are three main types of weather (Table 1) (Ginzburg et al., 2104, Ovcharova, 1988; Lukhtura, 2019).

Table 1. Classification of weather types according to the influence of O_2 content in the atmosphere on human well-being

Weather type	O_2content, %	People's well-being
Favorable	20.94…20.8	Good
Moderately unfavorable	20.79…19.5	Drowsiness, fatigue
Unfavorable	19.49…18	Headache, lossofconsciousness

At the level of O2 volumetric content in the air 20.94%, a person feels normal, but at O2<19.5%, signs of oxygen starvation (hypoxia) appear (Ginzburg et al., 2104, Ovcharova, 1988, Lukhtura, 2019): rapid breathing and heartbeat, decrease in arterial blood pressure, pale skin, weakness etc.

All these symptoms indicate that the body is trying to compensate for the lack of O2, forcing a person to be less active (DeMeo et al., 2004). If the measures to eliminate oxygen deficiency are not taken in time, hypoxia will progress. In old age, even a small degree of hypoxia triggers the activation of compensatory mechanisms, but they are not effective enough to maintain oxygen supply.

The oxygen concentration also affects the quality of life of the working-age population. According to the data given in (Petrov, 2015, Stozharov, 2007), a 1% decrease in O2 content in the air leads to a 30% decrease in a working capacity. According to some estimates (Ginzburg, 2014), not only in residential and work premises, but also on the streets of modern megalopolises, the percentage of oxygen in the ambient air approaches its content in exhaled air.

It seems that this phenomenon can be explained by an increase in CO2 concentration in the air. However, these 2 factors of influence on the human organism should not be mixed. Excitation of the inspiratory neurons of the respiratory center occurs not only with an increase in CO2 tension in the blood but also with a decrease in the oxygen tension. The nature of respiration with an excess of CO2 and a lack of O2 in the blood is different. With a slight decrease in the oxygen tension in blood, an increase in the breathing rhythm is observed, and with a slight increase in the carbon dioxide tension in the blood, a reflex deepening of respiratory movements occurs.

The hypoxic effect of the atmosphere manifests itself in the presence of an established low-pressure area (cyclone, shallow gully, low-gradient low-pressure field) in the warm front zone. The most pronounced hypoxic effect is observed with a combination of hypobaria and high air humidity.

Despite the obvious danger associated with industrial and automotive consumption of an important natural resource – an oxygen - by industry and vehicles, insufficient attention is paid to this issue. We consider the results of some studies devoted to theoretical methods for determining the oxygen concentration decrease in the atmosphere of industrial centers and megacities.

F.I. Lukhtura (2019) performed an analytical assessment of a possible decrease in the oxygen amount due to its flow rate from the surrounding atmosphere to metallurgical enterprises. It was assumed that the flow occurs through pinholes by a concentrated outflow of oxygen mass from a stationary ambient atmospheric air in the surface layer. This "hole" replaces the air suction lines of the consumer compressors. To determine the O2 concentration distribution in the surface layer of the atmosphere, the “reverse jet” method was used in a quasi-one-dimensional statement.

It was proposed to calculate the volumetric oxygen content in the surface air using the following formula:

$$CO2=CO2atm\cdot(1 - 1/R\text{-}\sqrt{(\rho\_hol/\rho\_O2\ )})\quad (1)$$

where CO2 and CO2atm are the volumetric oxygen content in the surface air and in the jet far-field, respectively; R is the radius of the waste flow ("jet") in the calibers of the hole; ρhol is the air density in the hole; ρO2 is the partial density of oxygen.

Since large industrial enterprises were removed from megacities, in Tashkent city as well, it does not seem appropriate to use the described method (equation (1)).

The closest topic to our investigation is the study by A.B. Kitsenko (2007), in which the process of the O2 concentration reduction in the urban air is related to the internal combustion engine operation. It was proposed to calculate the decrease in O2 concentration on the basis of the theory of diffusion of impurities (effluents) in a turbulent atmosphere.

3. Research methods

3.1 Theoretical study of oxygen flow rate

If we consider the decrease in O_2 concentration as a "negative" admixture, then the equation of turbulent diffusion can be applied to study its propagation in the atmosphere. It is necessary to take into account the random nature of the location of oxygen flow rates within the city associated with individual types of vehicles. That is, the problem under consideration can be represented as a boundary value problem (Kitsenko et al.,2007, Kitsenko et al., 2010).

This boundary value problem is solved using Green's function.

The equation of turbulent transfer for the mass concentration of impurity q, which is the mass of impurities in a unit air mass, has the following form:

$$\frac{\partial q}{\partial t} = -u\frac{\partial q}{\partial x} - v\frac{\partial q}{\partial y} - w\frac{\partial q}{\partial z} + K_{xx}\frac{\partial^2 q}{\partial x^2} + K_{yy}\frac{\partial^2 q}{\partial y^2} + \frac{\partial}{\partial z}\left(K_{zz}\frac{\partial q}{\partial z}\right) + f(x,y,z,t) \quad (2)$$

where {u, v, w} are the average velocities of the impurity component (or oxygen) along the x, y, z axes, respectively; the Ox and Oy axes are located in the horizontal plane; the Oz axis is directed vertically upwards; K_{xx}; K_{yy}; K_{zz} are the coefficients of turbulent diffusion (in further transformations of equation (2), it is assumed that $K_{xx} \to 0$, $K_{yy} \to 0$, i.e., diffusion occurs only along the Oz axis).

$$f(x, y, z, t) = \frac{P}{\rho}$$

where p is the volumetric density of outflow power of O_2, $\frac{kg}{m^3 \cdot s}$, in other words, the amount of impurity (kg) appearing in a unit volume (or disappearing from it (O_2)) per unit time due to external sources (outflows); ρ is the air density, ρ = 1.29 kg/m^3.

To solve the boundary value problem using Green's function, the territory of the city is represented in the form of some plane figure D, where the density of the probability distribution of vehicles over the city territory is g (x, y) ≈1 inside the area D and vanishes outside the area D (Fig. 1).

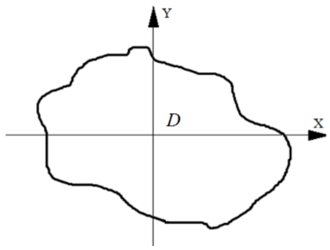


Figure 1. Schematic representation of the city territory for solving the boundary value problem

As a result of mathematical transformations, a solution to equation (2) was obtained in the following form (Kitsenko et al., 2007)

$$\Delta q = \frac{2}{\rho}\frac{N_{mot}}{S} M \sqrt{\frac{T}{\pi K_{zz}}}, \quad (3)$$

where Δq is the change in the oxygen concentration in the air due to the impact of vehicles; T is the time of increased traffic intensity, s; ρ is the air density, ρ = 1.29 kg/m^3; K_{zz} is the coefficient of turbulent diffusion K_{zz} = 0.01 $\frac{m^2}{s}$(Vorozhnin et al., 2012, Monin, 1965, Semenchin et al, 2010); M is the average amount of O_2 consumed by 1 car per 1 second, kg/(s · car); N_{mot} is the number of cars in motion, car; S is the city area (for Tashkent city S = 340 km^2).

Obviously, to define the theoretically possible value of Δ q with equation (3), it is necessary to determine some of the values entering it by a calculation or experimental method.

1. Determination of the number of vehicles N_{mot} driving during rush hours.

The total number of registered cars in Tashkent is approximately N = 500,000 units (Radkevich et al., 2019, Radkevich et al., 2020). According to the expert's opinion, a maximum of 65-70% of the total number is in motion, i.e.

$N_{mot} = 0.7 \cdot N = 0.7 \cdot 500{,}000 = 350{,}000$ *units*.

2. Determination of O_2 consumption per second for fuel combustion.

We assume the average fuel consumption as 10 kg per 100 km and the average car speed as V = 60 km/h. Then the fuel consumption per second is:

$$m_{fuel} = \frac{10}{\left(\frac{100}{60}\right) \cdot 3600} = 1{,}7 \cdot 10^{-3} \ \frac{kg}{(s \cdot car)}$$

Combustion of 1 kg of fuel consumes 3 kg of O_2.

So, $M = 1.7 \cdot 10^{-3} \cdot 3 = 5 \cdot 10^{-3}$ kg O_2 / (s·car)

3. Determination of the duration of increased traffic intensity (rush hour) T was made experimentally using sampling observation.

3.2 Determining the duration of increased traffic intensity

The city of Tashkent, from the point of view of traffic congestion, is a rather complex system: it consists of 11 districts; each district is crossed by a number of the highways classified as the main highways of the city, i.e. the most congested highways. A two-stage cluster sampling was applied for such a system.

To obtain data with a high degree of representativeness on the oxygen content in the breathing zone on the territories adjacent to the highways of the city of Tashkent, it is desirable to conduct a complete control, which is impossible in terms of time, labor, and material costs. The interaction and motion of gas in the surface area is a complex multifactorial process that can be preferably investigated by sampling methods.

We used a 2-stage cluster sampling.

1) The first stage is the presentation of the city territory as a cluster

2) According to the results of measurements (in summertime) at three points of each district, the average value of O_2 content (%) in the roadside zone was determined (Table 1):

1. The average value of the oxygen content in the roadside zones of the city was determined as X_{av} = 20.36%

2. The variance was determined as

$\delta = \sum(X - X_{av})^2 = 0.4158$

3. The standard deviation was determined by the following formula

$$\sigma = \sqrt{\frac{\delta}{m-1}}, \quad (4)$$

where m is the number of observations equal to the number of administrative units (districts)

$$\sigma = \sqrt{\frac{0{,}4158}{10}} = \sqrt{0{,}04158} = 0{,}2039 \ \%$$

4. We determine the number of districts (sample size) required for research, provided that with a probability of 0.954, the sampling error does not exceed 0.2% (± 0.1%) with a standard deviation σ = 0.2039

$$n = \frac{t^2\sigma^2 N}{N\Delta_x^2 + t^2\sigma^2} \qquad (5)$$

where t is the confidence coefficient, determined by the Table of Laplace (Table 2). We assume that $t = 2$

σ is the standard deviation, σ = 0.2039 %

Table 2. [23]

Probability P	0.683	0.954	0.997
Coefficient t	1	2	3

N is the volume of the general population, N = 11 - administrative districts, Δx – sampling error. $\Delta x = 0{,}2$ % ($\pm 0{,}1$%)

$$n = \frac{2^2 \cdot 0{,}2039^2 \cdot 11}{11 \cdot 0{,}2^2 + 2^2 \cdot 0{,}2039^2} = \frac{1{,}8293}{0{,}6063} = 3{,}017$$

so, the observations in 3 districts are enough for research.

5. Let us select 3 districts for further research. To do this, in each district, the O2 concentration was measured on each highway belonging to this district; this made it possible to determine the value of σ for each district. Table 3 shows the value of σ for each district.

For further research, we select the following districts (with the greatest values of σ, as the worst cases)

- Mirzo-Ulugbek district (σ = 0.15162 %; 8 highways)
- Yashnabad (σ = 0.14876 %; 6 highways)
- Chilanzar (σ = 0.14344 %; 9 highways)

Table 3. The values of σ for the districts of Tashkent city

Almazar	Yunusabad	Shaykhantakhur	Mirzo-Ulugbek	Mirabad	Yakkasaray	Yashnabad	Chilanzar	Uchtepa	Bektemir	Sergeli
0.12534	0.13871	0.12935	0.15162	0.13974	0.13991	0.14876	0.14344	0.13890	0.13670	0.14050

We determine the number of the highways to be surveyed in each of the selected district. Calculations showed that in the 1st district it was enough to examine 3 highways, in the other two districts, 2 highways were examined in each one.

The probability that the sampling error Δx will not exceed ± 0.1% was determined by:

$P=P_{city}{\cdot}P_{distr}=0.954^2=0.91012$

Conclusion: a sample consisting of 3 districts and 7 highways with a probability of 0.91 will provide an error ± 0.1% in determining the O_2 content in the urban atmosphere.

Therefore, according to calculations, to count the number of cars, it is enough to select 3 districts to ensure an error of ± 2 cars within 5 minutes, with an accuracy of 0.954.

3.3 Methods for conducting an experiment to determine the O_2 concentration and the rush hour duration in the roadside zones of the city of Tashkent

Our further task was to experimentally determine the O2 content near the highways and in residential areas of the city.

It was determined that the cluster sampling method would be applied in 3 districts of the city to survey 7 highways.

3.3.1 Equipment

For the measurements we used:

- Gas analyzer Smart Sensor ST8900 – a multi-gas portable meter capable of continuous monitoring of various gases: CO, H_2S, O_2, combustible gases. The O_2 measurement range is 0-30% with a resolution of 0.1 by volume, %.

- Anemometer TL-300 Digital Anemometer. Designed to measure wind speed (in the range 0 ... 30 m/s, precision: ± 5%), temperature (in the range -29 ... 70°C with a resolution of 0.1°C) and moisture content (in the range 0 ... 100% with a resolution 0.1%).

The atmospheric pressure was measured with an aneroid barometer

3.3.2. Measurement technique

Measurements of O_2 concentration, atmospheric pressure, air temperature, and wind speed were made for 5 minutes every next minute with the devices located at the breathing level, i.e. at a height of 1.5 meters from the soil surface:

a) in the roadside, i.e. in the area of sidewalks and sales outlets located in the immediate vicinity of them, etc.;

b) in residential areas located 100 meters far from the highways.

In addition, as mentioned earlier, the number of vehicles that passed during the measurement period was determined and the weather condition was recorded.

4. Results

4.1 Rush hour duration and modification of the Kitsenko equation

The number of cars was counted for 5 minutes at different times of the day from 6.00 to 22.00 on highways (4-lane roads) and 2-lane roads located nearby. The results were grouped by time intervals: 6.00 - 8.00; 8.00 - 10.00; 10.00 - 11.00; 11.00 - 13.00; 13.00 - 15.00; 15.00 - 17.00; 17.00 - 19.00; 19.00 - 20.00; 20.00 and later on.

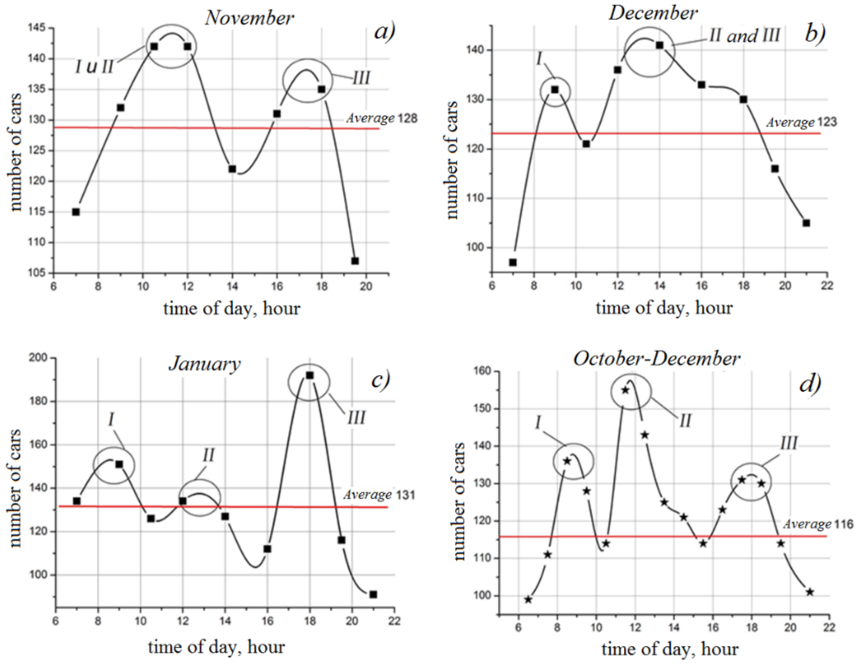
On the basis of multiple monthly counting of cars at the selected points, graphs of the dependence of road congestion on the time of day by months were built (Fig. 2). Fig. 2, d shows a more detailed generalized graph based on data for 3 months.

Based on the graphs obtained, the following conclusions can be drawn:

1. During the movement of cars in the period from 6.00 to 20.00 there were observed 3 peaks in traffic intensity: the I st – the start of work, the II nd - business activity, the III rd – the end of work. On graphs c), d) and e) all three peaks are clearly traced, on the graph a) the I st and the II nd peaks merge, on graphs b) and f) the II nd and the III rd peaks merge, on the graph g) the II nd peak is practically absent.

2. From the graphs (Fig. 2), we determine the average duration of each peak (Table 4). Based on Table 4, we will compose Table 5 – the rush hour duration

4-lane traffic



2-lane traffic

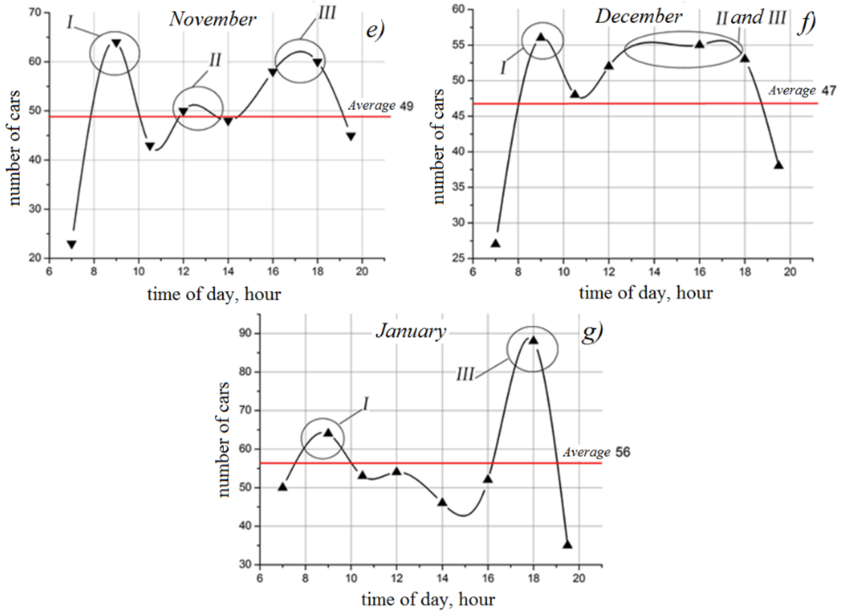


Figure 2. Graphs of changes in traffic intensity by the time of the day

Table 4. The rush hour duration in the graphs, Fig. 2

Fig. 2	I	II	III
a	8.00 – 13.00		15.00 – 19.00
b	8.00 – 10.00	11.00 – 18.00	
c	8.00 – 10.00	11.00 – 13.00	17.00 – 19.00
d	8.00 – 10.00	11.00 – 12.00	15.00 – 19.00
e	8.00 – 10.00	13.00 – 19.00	
f	8.00 – 10.00		16.00 – 19.00

Table 5. Average rush hour duration

№ of peaks	Duration T, hour						Average	Irregularity coefficient
	a	b	c	d	e	f		
I	5	2	2	2	2	2	2.5	0.5
II	0	7	2	1	6	0	4	0.571
III	4	0	2	4	0	3	3.25	0.813

For further calculations, the duration of the first rush hour (the most common value) was taken as T_{av} = 2.5 h (9000 s) with the irregularity coefficient $K_1 = 0.5$.

The average number of cars (see graphs in Fig. 2) estimated the road loading irregularity.

$$N_{averadge} = \frac{N_{av1} + N_{av2} + N_{av3} + N_{av4} + N_{av5} + N_{av6}}{6} = \frac{128 + 123 + 131 + 49 + 47 + 56}{6} = \frac{534}{6} = 89\ car$$

The irregularity coefficient is:

$$К_2 = \frac{N_{av}}{N_{max}\frac{89}{131}} \qquad (6)$$

Equation (3) is derived without considering the time interval variability of increased traffic intensity and the irregular distribution of cars throughout the city. Therefore, to use this equation, it is necessary to amend it to account for these irregularities. After the introduction of the coefficients K_1 and K_2, equation (3) will take the following form:

$$\Delta q = \frac{2}{\rho} \frac{N_{mot} \cdot K_2}{S} M \sqrt{\frac{TK_1}{\pi K_{zz}}} \qquad (7)$$

Substituting numerical values into equation (7), we obtain

$$\Delta q = \frac{2 \cdot 350000 \cdot 0{,}68}{1.29 \cdot 340 \cdot 10^6} \cdot 5 \cdot 10^{-3} \sqrt{\frac{9000 \cdot 0{,}5}{\pi \cdot 0{,}01}} = 0{,}00206 = 0{,}206\ \%$$

So, the theoretically possible reduction of oxygen content in the city atmosphere during rush hour may amount to 0.206%.

4.2 Determination of O_2 reduction

The average value of the difference in O_2 content before and after the peak of traffic intensity during 5 months (September – January 2019) was $\Delta q_{av\ oper}$ =0.224%.

Fig. 3, as an example, shows a graph of variation in O_2 percentage at a period from 6.00 to 20.00 plotted on the average values for November 2019. The dotted line shows a graph of traffic intensity change over the same period. As seen from Fig. 3, the end of the rush hour is accompanied by an increase in O_2 content. For example, after the end of the first rush hour (10.00 hours), the O_2 content increases to 19.99%.

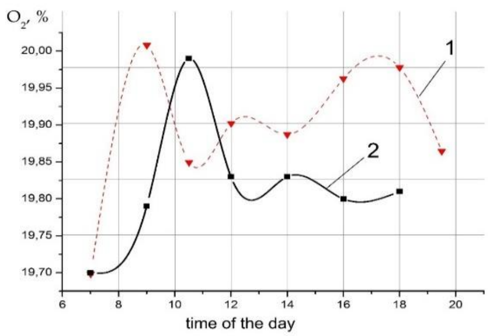


Figure 3. Combined graphs of changes in the number of cars and O_2 content in the air during the day for 2-lane traffic roads (November 2019)1 – number of cars; 2 – O_2 content

To test the possibility of using the modified Kitsenko equation (7) for practical calculations, let us compare the theoretical and experimental values of Δq:

$$\varepsilon = \frac{|\Delta q_{teor} - \Delta q_{exp}|}{\Delta q_{teor}} = \frac{|0{,}206 - 0{,}224|}{0{,}206} = 0{,}0873 \approx 8{,}73\%,$$

whence it follows that the modified equation (4) can be used for practical calculations of oxygen content reduction in urban air with an accuracy of approximately 9%.

Fig. 4 shows a diagram of agreement between theoretical and experimental values in O_2 concentration reduction after rush hour.

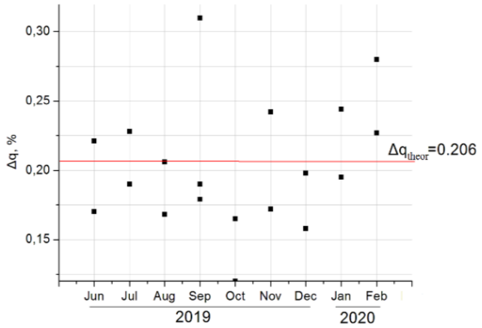


Figure 4. Diagram of agreement of experimental values of oxygen concentration reduction Δq

Based on the above diagram, it can be concluded that the most of experimentally obtained values of Δq lie in the range of ± 20% of theoretical values. The accuracy of the results corresponds to the recommendations stated for environmental studies (Kozlov, 2014).

So, if the O_2 concentration before rush hour approaches the critical value (19.6 ... 19.54%), the population should be warned to take precautions.

Obviously, the calculated value of Δq was obtained at certain values of *S*, *T*, N_{mot}, which correspond to the current state of road transport in Tashkent. If any of these indices change, it is necessary to correct equation (7).

As a result of the experiment, the following dependencies were obtained (Fig. 5).

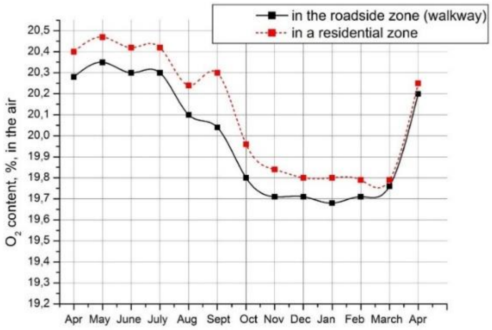


Figure 5. Average monthly values of O_2 content in urban air during the day for 4-lane traffic roads

The graph shows that the O_2 content in urban air does not remain constant throughout the year. From October to March inclusive, the oxygen content is noticeably reduced, which is explained by the complete cessation of the active life of green plants, and a decrease in the length of daylight hours.

Beginning from October, the O_2 content is ≤ 19.8%; i.e. it approaches a hazardous index for human health (19.6 – 19.5% O_2). On some days, the oxygen content drops to 19.2%.

During the year, 39 days with low O_2 content were observed. A clearly defined dependence of the O_2 content reduction on the meteorological conditions was not revealed.

It is clear that the seasonal O_2 content is noted not only in the urban area but also outside it. To assess the impact of urban transport on O_2 content, comparative measurements of O_2 content within the city area and outside it were made.

The decrease in O_2 content in the city air averages Δq = 0.3 ... 0.4% in comparison with the suburban air.

4.3 Harm definition from an oxygen concentration reduction

The visual representation of environmental damage can be obtained through its monetary value.

For an approximate assessment of the harm caused to the urban population by depleted air, we propose the following formula:

$$Harm = 6 \cdot k_1 \cdot k_2 \cdot Wm_{av} \cdot N_{mc} \cdot \Delta q \qquad (8)$$

where 6 is the duration of the period with reduced O_2 content, months;

k_1 is the coefficient that accounts for the share of vehicles in the reduction of O_2 content; $K_1 = 0.8$ (Radkevich et al., 2014);

k_2 is a coefficient that accounts for the loss in labor productivity of the working-age population at the O_2 content reduction per 1%; $K_2 = 0.3$ (Petrov, 2015, Stozharov, 2007)

Wm_{av} the average monthly wage, for the city of Tashkent for December 2019

Wm_{av} = 3.2 million soums ≈ 336 USD per month (the wage reflects, to some extent, the labor productivity.)

$N_{wor\ pop}$ - the number of the working-age population, in Uzbekistan the share of the working-age population is 68% (https://countrymeters.info/ru/Uzbekistan)

$$N_{wor\ pop} = N \cdot 0.68 \qquad (9)$$

where N is the total population, for the city of Tashkent N = 2538.4 thousand people (01.07.2019)

$$N_{wor\ pop} = 2538.4 \cdot 0.68 = 1726.1 \text{ thousand people.}$$

Δq is a decrease in O_2 content in the city atmosphere compared to O_2 content outside the city, Δq = 0.4%.

$$Harm = 6 \cdot 0.8 \cdot 0.3 \cdot 336 \cdot 1726.1 \cdot 10^3 \cdot 0.4 = 334.1 \text{ million c.u./year.}$$

5. Discussion

The results of the experiments and calculations show that the problem of low oxygen content in the urban atmosphere is very acute.

However, the Hydrometeorological Center in Tashkent does not perform the measurements of O_2 content.

According to (Ginzburg et al., 2014), the population in the Russian Federation and other countries is informed about the oxygen content in the air; the content is measured based on calculations using the classical formula:

$$C_{O2}\ (g/m^3) = 83^{(p-e)}/T \qquad (10)$$

where P is the pressure, GPa, e is the absolute humidity, GPa, T is the temperature, K.

To compare the results obtained in our experiments and the ones determined by formula (10), we give graphs of O_2 content in percent during December 2019 (Fig. 6). Based on the comparison of the graphs, it can be concluded that the values of the O_2 concentration, determined by calculation, are greatly overestimated, which can cause unreasonable reassurance.

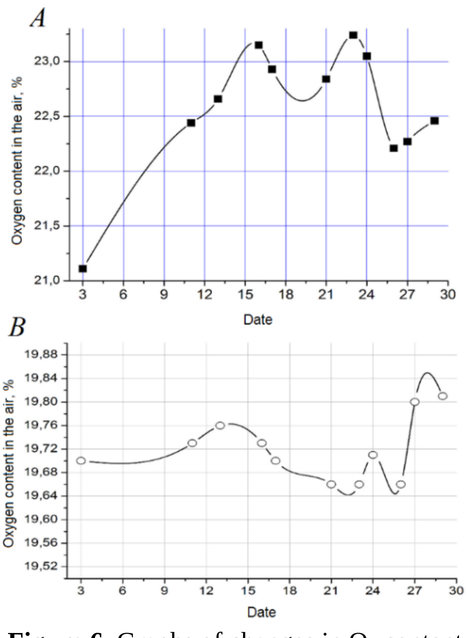


Figure 6. Graphs of changes in O_2 content (December 2019): a) calculated value, b) experimental value

It should be noted that the oxygen content in the air of Tashkent in residential areas fluctuated during the year from 19.8 to 20.48%, that is, it was reduced relative to the normal content of 20.8%. Similar fluctuations are typical for other large cities in the world. According to the data given by Zaporozhets et al. (2018), during the year, the oxygen content in the air fluctuates from 20.65 to 20.85% in Berlin, from 20.65 to 20.8% in Canberra, from 20.38 to 20, 73% in New Delhi.

Fluctuations in O_2 concentration in Tashkent near the highways amounted to 19.68 - 20.29%, that is, the minimum values enter the “uncomfortable zone”.

The results obtained are generally consistent with the results of other researchers. For example, the studies conducted in the city of Mariupol (Lukhtura, 2019) to assess the oxygen flow rate near industrial enterprises show that at a distance of 100-200 m from the place of flow, the oxygen concentration is reduced relative to the standard values. In our studies, it was also revealed that at the distance of 100 - 150 m from highways, the oxygen concentration in the residential area approaches the standard values.

The studies conducted by Kitsenko et al. (2007) indicated that near the highways the volumetric oxygen content in the air can drop to 18.32%, and at this value, oxygen starvation can occur. This result is significantly lower than the value obtained in this study for the minimum oxygen content (19.68%). The difference in results should be explained by the conditions of the studied objects. Kitsenko's research was carried out in Kharkov (Ukraine), which is a large industrial center and, therefore, a more significant decrease in the concentration of oxygen in its air is explained by the impact of industrial facilities.

The results of this study were limited in space by the territory of the city of Tashkent, and in time - by one year. The application of the obtained equation for calculating the decrease in oxygen concentration is possible for other cities, provided that the coefficients of uneven traffic are adjusted for the conditions of the selected city.

The methodology for assessing the monetary damage from a decrease in oxygen concentration was developed for the conditions of the city of Tashkent, for its application in the conditions of other settlements, it is necessary to clarify the data on the duration of the period with a reduced oxygen content.

6. Conclusion

As a result of the study, a tangible effect of road transport on a local decrease in the O2 percentage in the urban air was revealed. Since the health and efficiency of the population largely depend on this indicator, in our opinion, the following measures should be taken:

1. To conduct regular monitoring of O2 content in the urban atmosphere and inform the population about O2 concentration. Monitoring can be done indirectly, by assessing the traffic intensity and subsequent calculation using the modified Kitsenko equation.

2. To include consideration of the oxygen flow rate problem in training courses to prepare future environmentalists to prevent and mitigate this problem.

3. To develop measures for the reduction of the impact of vehicles on the environment by the transition to alternative fuels, electric vehicles, production of small cars, and traffic organization.

4. To increase the degree of city greening, including protective greening of the highways and streets to reproduce oxygen. Currently, only 26% of city streets are greened on two sides.

The need for such measures is dictated by the rapid growth of motorization in Uzbekistan. If the current density of the car park in Tashkent is about 200 cars per 1000 inhabitants, it is expected to double by 2030. Therefore, preparation for the operation of such a number of vehicles must be dealt with now.

The direction of further research should be the study of the distribution of oxygen concentration in the urban atmosphere depending on the height above the earth's surface (taking into account vertical and horizontal air movements), as well as a differentiated assessment of the impact on the oxygen content of various anthropogenic objects (transport, industrial enterprises and landfills).

References:

Chirkov, V. (2015). The problem of oxygen depletion of the atmosphere and the concept of its solution. *Energy bulletin, 19*, 64-72

DeMeo, D. L., Zanobetti, A., Litonjua, A. A., Coull, B. A., Schwartz, J., & Gold, D. R. (2004). Ambient Air Pollution and Oxygen Saturation. *American Journal of Respiratory and Critical Care Medicine, 180*(4), 383-387. doi: 10.1164/rccm.200402-244OC

EEA Report No 24/2018. (2019). Europe's urban air quality — re-assessing implementation challenges in cities. European Environment Agency. ISBN 978-92-9480-059-6

Ginzburg, A. S., Vinogradova, A. A., Fedorova, E. I., Nikitich, E. V., & Karpov, A. V. (2014). Content of oxygen in the atmosphere over large cities and respiratory problems. *Izvestiya, Atmospheric and Oceanic Physics, 50*, 782-792. https://doi.org/10.1134/S0001433814080040

Huang, J., Huang, J., Liu, X., Li, Ch., Ding, L., & Yu, H. (2018) .The global oxygen budget and its future projection. *Science Bulletin, 63*(18), 1180-1186, ISSN 2095-9273, https://doi.org/10.1016/j.scib.2018.07.023

Keeling, R. F. (2013). Atmospheric oxygen and APO data for Alert, Canada and the South Pole, Retrieved from http://scrippso2.ucsd.edu/osub2sub-data (for oxygen data), and http://scrippso2.ucsd.edu/apo-data (for APO data), accessed October 11, 2020.

Keeling, R. F. (1988). Measuring correlations between atmospheric oxygen and carbon dioxide mole fractions: A preliminary study in urban air. *Atmosphere Chemistry, 7*, 153-176. https://doi.org/10.1007/BF00048044

Kitsenko, Yu. A., Kitsenko, L. N., & Kitsenko, A. B. (2010). Calculation of emissions of a single source of impurities using Green's functions. *Bulletin of the Kharkov National Automobile and Highway University, 49*, 133-138.

Kitsenko, A. B., Pyatak, A. I., & Kitsenko, Yu. A. (2007). Change in the concentration of atmospheric oxygen due to its absorption by motor transport. *Automobile transport (Kharkov), 20*, 36-40.

Kozlov, M. V. (2014). Environmental Research Planning: Theory and Practical Recommendations. KMK Scientific Publishing Association, Moscow, pp. 101-104

Lukhtura, F. I. (2019). On the ecology around the industrial areas of Mariupol. *Bulletin of the National Technical University "KhPI". Series: New solutions in modern technologies, 2*, 67-74

Monin, A. S., & Yaglom, A. M. (1965). Static hydromechanics. The mechanics of turbulence. Nauka, Moscow, 359-408.

Ovcharova, V. F. (1988). Homeokinesis in weather hypoxia and hyperoxia. Proceedings of the International Symposium WMO/WHO/UNEP in the USSR, Leningrad, September 22-26, 1986, Leningrad, Gidrometeoizdat, vol. 2., 142-149.

Petrov, V. N. (2015) .Features of the influence of the partial gradient of oxygen density in the atmospheric air on the health of the population living in the Arctic zone of the Russian Federation. Bulletin of the Kola Scientific Center of the Russian Academy of Sciences, 3 (22), 82-92.

Population of Uzbekistan. Countrymeters. (Electronic resource). Retrieved on April 20. 2020. from: https://countrymeters.info/ru/Uzbekistan

Radkevich, M., & Salokhiddinov, A. (2014) The method of evaluation of greenhouse gas emission from car-road complex and its application in estimation of caused losses. *European Science Review, 11-12*, 59-63.

Radkevich, M., & Shipilova, K. (2019). The processes of accumulation and transport of automobile waste in the city of Tashkent. *Waste forum,* 3, 211-218

Radkevich, M., Shipilova, K., Myagkova, N., Abdukodirova, M., & Gapirov, A. (2020). Assessment of some indices of environmental sustainability of transport in Tashkent. *Waste forum*, *1*, 16-32.

Scripps O2 Global Oxygen Measurements (2020). Retrieved on October 18. 2020. from https://scrippso2.ucsd.edu/

Semenchin, E. A., & Kuzyakina, M. V. (2010) Method of calculating the vertical component of the turbulent diffusion coefficient. *Scientific Journal of KubSAU, 62*(08), 20-28.

Stozharov, A. N. (2007) Medical ecology. Vysshayashkola, Minsk, pp. 147-166.

Vorozhnin, V. S., Markelov, Yu. I., Davydov, V. B., Teterin, A. F., & Poddubny, V. A. (2012). Determination of meteorological parameters in the model of dispersion from the highway. *Bulletin of Nizhnevartovsk State University, 4*, 73-78.

Zamolodchikov, D. G. (E-resource) Lack of oxygen: myth or reality? Retrieved on November 11, 2020. from https://refdb.ru/look/1580574-pall.html

Zamolodchikov, D. G. (2006). Oxygen is the basis of life. *Bulletin of the Russian Academy of Sciences, 76*(3), 209-218.

Zaporozhets, A. O., Redko, O. O., Babak V. P., Eremenko, V. S., & Mokiychuk V. M. (2018). Method of indirect measurement of oxygen concentration in the air. *NaukovyiVisnyk NHU*, *5*, 105-114.

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