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ТРУДЫ ИНСТИТУТА ГИДРОМЕТЕОРОЛОГИИ ГРУЗИНСКОГО ТЕХНИЧЕСКОГО УНИВЕРСИТЕТА ТОМ № 116

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Mathematical Modelling of the Atmosphere Pollution For Extreme Situations

Introduction

The sources for atmosphere pollution are basically of two types: natural and artificia# The first comprises volcanoes, dusty storms, forest combustion, erosive soil dust, plants dust, micro-organisms and other factors. Anthropogenic sources of environmental pollution are more diverse, powerful and enduring as compared to natura# One more source for anthropogenic pollution is deleterious substances entered into the environment during military conflicts. It is natural that nobody thinks of ecology in such cases, a relatively weak system of environmental protection falls fully out of order, new sources of environmental pollution emerge. Results of scientific research demonstrated that in the years 1942-1943 pollination of Caucasian Glacier significantly increased (the process was caused by military operations under way in the Northern Caucasus). During Iraq-Kuwait conflict (1991) up to million tons of oil was being daily burned on oil-mining sites. Huge amount of soot, carbonic acids, sulfur dioxide and other substances was being dispersed into atmosphere [1,2]. As seen above, confrontations between countries plays a very significant role in the process of environmental pollution. Not only population suffers from the polluted environment, additives transmitted through air and sea flows cause global pollution of the whole environment. Therefore this issue needs to be examined in more detai# We decided to study the problem on the example of the basic conflict zone – Caucasus, as Georgia is located in the center of Caucasian zone, it is natural, that its environment is affected by USA-Iraq conflicts, as well as Russian-Chechnyan, conflicts. Both local and global distribution of deleterious substances dispersed in the atmosphere from the conflict zone as a result of using various weapons are also to be studied.

Studying the air pollution with biological and chemical substances on the example of South Caucasus and South-West Asia is especially interesting. According to the news materials dealing with the conflict developed in South Caucasus certain chemical weapon was released during the conflict. It is also known that the Russians released vacuum and cassette air bombs while bombing Groznyy. The Russian Federal powers have used chemical weapons as wel# In the region where these chemical weapons had been released the level of concentration of poisonous substances has been increased from 2000 to 7000 points[3-5]. According to the data of military experts Saddam Hussein used the poisonous weapons 14 times during the Iran-Iraq war. According to the news materials dealing with the "Desert Strom" the American soldiers had released the shells containing the depleted uranium, the same weapon was used during the war in Yugoslavia. The same chemical weapon seems to have been released in 2003 in the US-Iraq conflict, since the instances of terminal diseases (cholera and typhus) in children were recorded; the infection was rapidly spread due to low-quality drinking water. As for biological weapons, Iraq has released weapons causing the diseases like gangrene, camel virus etc. These weapons are: toxin, anthrax, nytroxine etc[1,3,5].

Investigation Of Harmfull Substances Transfer And Diffusion In The Atmosphere By Empirical Model

The main sources of pollution during conflict situations are the following: Used missiles; Used military shells; Burning of oils and oil products during war. Now we will investigate harmful substances transfer and diffusion in the atmosphere resulted from burning of oils and oil products during war. The issue was studied on the examples of US-Iraq, Iraq-Kuwait, Russia-Chechnya and US-Afghanistan conflicts. To calculate the land surface concentrations of hazardous substances dispersed into the atmosphere we obtained authentic materials dealing with the average amount of hazardous substances dispersed into the environment daily, weekly, monthly and annually during each conflict, afterwards the substances had been classified. We calculated the concentrations of hazardous substances dispersed into the atmosphere on the basis of analysis as well as statistic models. The following points were studies in both cases:transition of hazardous substances emitted in atmosphere as a result of oil products combusting during wars; transition of aerosols and gas substances from used military shells in space and time.

Maximum value of the earth surface concentration of harmful substances Cm (mg/m^3), which in case of non-favorable meteorological conditions is reached at the distance. Xm (m) from the round pipe source, can be defined by the formula [6-8]:

$$C_m = \frac{AM\eta mnF}{H^2\sqrt[3]{V_1\Delta T}}, \qquad (1)$$

where A is a coefficient of temperature stratification of the atmosphere (A=200 for the Georgian conditions); M-is mass of harmful substances ejected away from the source in unit of time (gr/c); F is non-dimensional coefficient which indicate velocity of harmful substances deposition in the atmosphere. For aeral harmful substance and small dispersied aerosols (dust, soot) F=1. For large dispersied dustand aerosols, when coefficient of peelings is more, than 90% F=2. When coefficient of peelings is between 75% and 90% F=2.5. When coefficient of peelings is not exceed 75%, then F=3; H is height of the source (m); ΔT is a deference between the temperature of the ejected harmful substances and the temperature of the environment; η is non-dimensional coefficient, which describes influence of the orography on the distribution of harmful substances in space. For the plate localite, when change of high is less than zom on 1 km then η =1. Opposite value of η is defined from the cartographical maps (no less two kilometer away from the source; V_1 is mass of harmful substances ejected from the pipe source in the unite time and value of V_1 can be defined by the formula:

$$V_1 = \frac{\pi D^2}{4} w_0 , \qquad (2)$$

where, D is a diameter of the pipe; w_0 is an average velocity of harmful substances which is ejected from the pipe (M/C); m and n are non-dimensional coefficients describing conditions of the ejection and defined as it was suggested in [6,7]. Calculations have been performed on the basis of the considered model for the value of ground concentration of harmful substances sprayed out in the atmosphere: in case when one borehole is exploded; in case when several boreholes are exploded at the same time.

At first we performed calculations for No_x, possible concentrations of No_x were calculated for each borehole, when the heights the sources of harmful substances sprayed out in the atmosphere were h=0.5, 1, 5, 10 and our primary data were D=0.4 (m) for pipe diameter, the speed of emerging admixtures W = 12 (m/sc), temperature change of atmosphere and admixtures $\triangle T$ = 380^{0}C and the weight of the admixture **M** = 10 m/sc. The results obtained are displayed on Table 4, as seen from the table, the more the speed of admixture emergence W_0, the less is the maximum value of ground concentration which is natural since in case of the high admixture emergence speed the height of its vertical ascent grows and consequently the maximal value of ground concentration is achieved far off the source. The results of concentrations calculated for all possible values of W_0 and by various wind speeds are displayed on Table 1.

Table 1 Concentrations of NO_x ejected from the 500 pipes (D=20 m)

M(g/sc)	Cm	Xm	X	U(m/sc)	Cmu	Xmu	C(mg/m^3)	Cmx	Umx	C_{342ze}
5250	2091	114	20000	1	12,8	342	3,15	3,52	112	1089
5250	2091	114	20000	3	40	342	3,15	3,52	112	1089
5250	2091	114	20000	5	69,4	342	3,15	3,52	112	1089
5250	2091	114	20000	10	151	342	3,15	3,52	112	1089
5250	1046	128	20000	1	5,06	384	1,76	1,99	140,8	545
5250	1046	128	20000	3	15,7	384	1,76	1,99	140,8	545
5250	1046	128	20000	5	27,02	384	1,76	1,99	140,8	545
5250	1046	128	20000	10	58	384	1,76	1,99	140,8	545
5250	697	137	20000	1	2,94	411	1,25	1,43	161	363
5250	697	137	20000	3	9,09	411	1,25	1,43	161	363
5250	697	137	20000	5	15,6	411	1,25	1,43	161	363
5250	697	137	20000	10	33,2	411	1,25	1,43	161	363
5250	523	144	20000	1	2	431	0,98	1,13	177	272
5250	523	144	20000	3	6,17	431	0,98	1,13	177	272
5250	523	144	20000	5	10,5	431	0,98	1,13	177	272
5250	523	144	20000	10	22,4	431	0,98	1,13	177	272

Remark: the results of calculations represented in Tab. 1 were obtained by the following values of parameters: A=200; h=1; D=20; ΔT=380˚; F=1; η =1.

According to the table, the maximal value of ground concentration is highest (C_{mu} = 2867 mg/m^3) when the wind speed U = 10 m/sc and W_0 = 16 m/sc. In order to calculate concentration values for the same case we assumed that we had punctual source with 20 m diameter and 1 m height, with 5250 g harmful substance emerging. This case was considered for various wind speeds and various W_0s and the obtained results are given in Table 2.

Table 2 Concentrations of NO_x ejected from one pipe for different value of W_0

Wo	M(g/sc)	Cm	Xm	X(km)	**U(m/sc)**	Cmu	Xmu	C(mg/m^3)
4	10	4290	4,5	20000	1	183	14	0,27
4	10	4290	4,5	20000	3	663	14	0,27
4	10	4290	4,5	20000	5	1250	12	0,27
4	10	4290	4,5	20000	10	2867	5,15	0,27
8	10	2145	5	20000	1	71	15	0,15
8	10	2145	5	20000	3	250	15	0,15
8	10	2145	5	20000	5	468	9	0,15
8	10	2145	5	20000	10	1102	7	0,15
12	10	1430	5,4	20000	1	41	16	0,11
12	10	1430	5,4	20000	3	142	16	0,11
12	10	1430	5,4	20000	5	264	16	0,11
12	10	1430	5,4	20000	10	624	9	0,11
16	10	1072	6	20000	1	28	17	0,09
16	10	1072	6	20000	3	95	17	0,09
16	10	1072	6	20000	5	176	17	0,09
16	10	1072	6	20000	10	416	11	0,09

Table 2 shows that W_0 = 4 m/sc and the maximal value of ground concentration during dangerous wind speed is C_{mu} = 2091 and is achieved at 114 m and under the same conditions, i.e. when W_0 = 4 m/sc and the wind speed U = 1 m/sc, maximal concentration is reduced C_{mu} 12.8 mg/m^3 – at 342 m. The concentration value at 342 m during the dangerous wind speed was calculated and C = 1089 mg/m^3 was obtained which essentially differs from maximal concentration values when U = 1, 3, 5, 10 (m/sc).

Similar results were obtained when W_0 = 4, 8, 12, 16 (m/sc).

Remark: the results of calculations represented in Tab. 1 were obtained by the following values of parameters: A=200; h=0,1; D=0,4; ΔT=380˚; F=1; η =1.

Investigation of The adverce Substances Distribution in the Attmosphere on the Basis of Analitical Model

Let us assume that a source of harmful substances is located at altitude H_0 and it's ejected q kg substances in unity of time. Also let us assume that along the axis ox is blowing wind with the constant velocity. Our aim is to calculate the adverse substances concentrations in every point (x,y,z) of investigated area at the moment t. To solve above mentioned problem we use the following equation [6,7]:

$$\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial x}+V\frac{\partial C}{\partial y}+W\frac{\partial C}{\partial z}=\frac{\partial}{\partial x}(\nu_1\frac{\partial C}{\partial x})+\frac{\partial}{\partial y}(\nu_2\frac{\partial C}{\partial y})+ \qquad (3)$$

$$+\frac{\partial}{\partial z}(\nu_3\frac{\partial C}{\partial z})+W_0\frac{\partial C}{\partial z}-\alpha c,$$

where $C-$is concentration; U,V,W are the axis components of wind velocity along axis $x,y,z,$; $t-$is time; $\nu-$ is coefficient of turbulent diffusion ; $W_0-$is the velocity of substance's deposition; $\alpha-$is the coefficient that determines the velocity of substance concentration chances during the processes of substance decomposition and transformation. For passive reagents $\alpha=0.$ For light substances $W_0=0.$

In the first approximation , when $W_0=V=W=\alpha=0;$ $U=const$ and $\nu_1=\nu_2=\nu_3=\nu=consat$, the equation (3) will have the following form:

$$\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial x}=\nu(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}+\frac{\partial^2 C}{\partial z^2}), \qquad (4)$$

The equation (4) is solving with the following initial and boundary conditions :

$$C=q\delta(x)\delta(y)\delta(z-H), \text{ when } t=0,$$

$$C=0, \text{ when } |x|\to\infty \text{ and } |y|\to\infty,$$

$$C=0, \text{ when } z\to\infty, \qquad (5)$$

$$\nu\frac{\partial C}{\partial z}=0, \text{ or } C=0, \text{ when } z=0.$$

where $\delta(x)$ -is delta function of Dirak.

If in (4) we use limit when $t\to\infty$, then we will have the following stationary solution:

$$C=\frac{q\exp(-\frac{U(R-x)}{2\nu})}{2\nu\pi^{\frac{3}{2}}R}\int_0^\infty\exp[-(\eta+\frac{UR}{4\nu\eta})^2]d\eta=\frac{q\exp[-\frac{U(R-x)}{2\nu}]}{4\nu\pi R}, \qquad (6)$$

In case of turbulent kinematic coefficients along axis $ox, oy,$ and oz are different the equation (4) has the following form:

$$\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial x}=\nu_1\frac{\partial^2 C}{\partial x^2}+\nu_2\frac{\partial^2 C}{\partial y^2}+\nu_3\frac{\partial^2 C}{\partial z^2}, \qquad (7)$$

Solution of the equation (7) with the initial and boundary conditions (5)
In is this expression pass into limit when $t\to\infty,$ then we obtain the following formula:

$$C=\frac{q}{4\pi\sqrt{\nu_1\nu_2\nu_3}}[\frac{\exp(-\frac{U}{2\nu_1}(R_1\sqrt{\nu_1}-X))}{R_1}\pm\frac{\exp(-\frac{U}{2\nu_1}(R_2\sqrt{\nu_1}-X))}{R_2}]$$

and

$$R_1 = \sqrt{\frac{x^2}{\nu_1} + \frac{y^2}{\nu_2} + \frac{(z-H)^2}{\nu_3}} \quad R_2 = \sqrt{\frac{x^2}{\nu_1} + \frac{y^2}{\nu_2} + \frac{(z+H)^2}{\nu_3}} \qquad (8)$$

(8) shows that the dimensions of R_1 and R_2 are $[R]$ = sc$^{1/2}$.

The equation (3) can be solved only when v_3 is the function of z, is possible only through numerical methods. For analytic solution we shall consider that it is a constant value and alters only according to the temperature stratification of atmosphere. Pasquill classification was applied for the characterization of atmosphere conditions[9].

Table 3.values of turbulence cinematic factors corresponding to various temperature stratifications

Stability classes	Condition of temperature stratification	$v_1 = v_2$ (m^2/sc)	v_3 (m^2/sc)	v (mean)
1	Strong non-stability	250-260	45-50	185
2	Medium non-stability	100-110	15-20	61
3	Weak non-stability	30-35	6-7	19.5
4	Indistinguishable balance	10-15	2-3	7.5
5	Stabile condition (weak)	3-5	0.4-0.5	2.23
6	Stability	1-1.5	0.2-0.3	0.75

It is clear that turbulent mixing is so great for the first three classes that dangerous concentrations of discharged substances will never concentrate near the earth surface. Therefore no calculations are needed for these classes (especially for classes 1 and 2). Consequently the calculations shall be conducted for the last three classes. They correspond to the abnormal meteorological conditions that contribute to the increasing concentration of harmful substances in the atmosphere.

Three-dimension pictures of concentration distribution have the following appearance for the stationary case Fig. 1-3. Fig. 1-3 depicts the case when the spray-out of harmful substances in the atmosphere is the result of the explosion of more than 500 boreholes. Here the following values serve as initial data: q = 5250 g, U = 1, 3, 5, 10 m/sc. The results are given for various h-heights, the v cinematic factor of turbulence is considered to be a constant value and changes only according to the change in temperature stratification of atmosphere. Since 6 classes of stability correspond to the temperature stratification, we have 6 possible values of v for C.

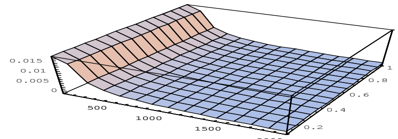

Fig1**.** Strong non-stability q=5250 g/sc u=3 m/sc ν =183 m^2 /sc y=0.00001 h=1 m

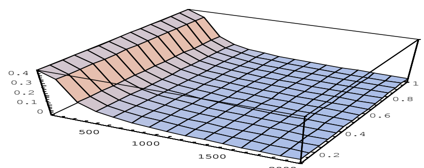

Fig 2.. Indistinguishable balance ($\nu = 7.5$ m^2 /sc)

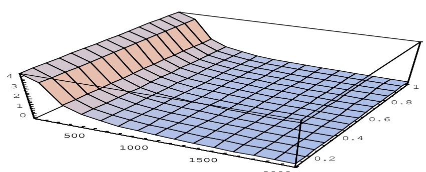

Fig. 3. Stability ($\nu = 0.75$ m^2 /sc)

Concentration distributions are given for each stratification conditions. As the figures show, the concentration values are significantly small during non-stability (first three classes) which is natural since turbulent mixing is so high for the considered three classes that minor harmful substances are accumulated near the earth surface. As for the last three classes (stability), it seems that concentrations are considerably high. Some Results of Calculations by Analytical Models With Account of Atmosphere Stratification

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მათემატიკური სტატისტიკური და ემპირული მოდელებით შესწავლილია გარემოს (ლოკალური, რეგიონალური, და გლობალური მასშტაბების) შესაძლო გაბინძურება საქართველოსა და შუა აღმოსავლეთის ტერიტორიებისათვის. წარმოდგენილია რიცხვითი გათვლების შედეგები.

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Mathematical Modelling of the Atmosphere Pollution For Extreme Situations./Samkharadze I., Davitashvili T., Zotikisvili N., Geladze G/Transactions of the Georgian Institute of Hydrometeorology.-2011.-v.116. p.93-96-Eng; Summ.Georg; Eng; Russ.
On the basis of the mathematical, statistical and empirical modeling possible pollution of environment (local, regional, global scales) is estimated. With the purpose to estimate possible distribution harmful substances on the territory of Georgia and Middle East regions, numerical experiments is conducted. Time-space distribution of harmful substances on the territory of Georgia Middle East regions is obtained. The results of the computations, the level of harmful substances' concentrations are given.

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Математическое моделирование загрязнения атмосферы экстремальных условиях./Самхарадзе И.Н.., Давиташвили Т.П.,Зотикишвили Н. Ш, Геладзе Г .Ш./ Сб.Трудов Института Гидрометеорологии АН Грузии. –2011. – т.116. – с.93-96- Анг.; рез. Груз., Анг.,Русск.
На основе математического, статического и эмпирического моделирования изучается пространственно-временное (локальногых, региональных и глобальных масштабов) распределение продуктов военных деиствий на териториях Грузий и Ближнего Востока . Представленный результаты численных расчетов