

APPENDIX Q

AIR QUALITY MODEL METHODOLOGY

Air quality

The software "УПРЗА Эколог" 4 is developed by company Integral, the leader in environmental software development in Russia. The company has headoffice in St.Petersburg and 32 regional offices and dealers across the CIS. The company has 20 years of experience in the field of environmental software development. Portfolio of the company includes software for calculation, data base management, etc. in the field of air protection, waste management, assessment of water pollution, sanitary acoustics, sanitary monitoring. The software are used in development of environmental protection documents for various projects, projects for calculation of threshold emission limits, calculation/assessment of compensation of negative impact (damage) on environment. The users include ecologists working for industrial facilities, specialists involved in development of environmental and design documentation, state environmental authorities, health officers, universities. The software has all required certificates (for reference see <https://integral.ru/licence.html>)

Unified software for calculation of air pollution (УПРЗА) 'Ecolog' enables calculation of concentration of air pollutant substances according to the methodology described below (Technical Regulations for Calculating Threshold Limit Values of Emission (TLVE) of Harmful Substances into the Ambient Air).

Major functional capabilities of the software:

Calculation of near-ground concentration of individual pollutants and groups of substances with summary negative impact. Number of substances and groups in calculation is not limited. The software enables calculation (average for 20-30 min interval) of substances in near ground stratum in unfavourable meteorological conditions with consideration of conditions in the area based on the parameters of the source of emission. Results of calculation are presented in shares of the threshold value in mg/m³ units. The output is presented in tabular and graphical format. The software automatically indicated locations with maximum concentration of pollutants.

Compliance of one time maximum emission with the threshold automatically means compliance with the average daily threshold. This conclusion is based on experimental and theoretical data on the ratio of 'average annual' and 'maximum one time' near ground concentration. Average annual concentrations based on the mentioned above generally accounts for (one time max value)/25, whereas average daily – is not less than (one time max value)/10. This enables to conclude that compliance with one time value threshold requirements automatically means compliance with average annual and average daily limits.

Technical Regulations for Calculating Threshold Limit Values of Emission (TLVE) of Harmful Substances into the Ambient Air

Requirements for determining TLVE

1. The following requirements must be met for determining the TLVE:

$$\frac{c_m}{TLVE_m} \leq 1 \quad (A1)$$

where:

C_m – is the ceiling level of concentration of harmful substances calculated in the surface layer of ambient air (mg/m^3) for jointly all the sources of pollution;

TLVC $_m$ – is a corresponding single ceiling exposure concentration of harmful substances, mg/m^3 ;

2. In the case of presence of several harmful substances of combined impact simultaneously in the ambient air, the following requirements must be met:

$$\frac{C_{m1}}{TLVE_{m1}} + \frac{C_{m2}}{TLVE_{m2}} + \dots + \frac{C_{mn}}{TLVE_{mn}} \leq 1 \quad (\text{A2})$$

where:

$C_{m.1}, C_{m.2} \dots C_{m.n}$ – are the calculated ceiling levels of concentration of harmful substances in the same zones of the surface layer of ambient air;

TLVC $_m1, \text{TLVC}_m2 \dots \text{TLVC}_m.n$ – is a corresponding single ceiling exposure concentration of harmful substances, mg/m^3 .

3. In the case of planning and implementing activities in resorts and protected areas, 1 must be replaced by 0.8 in the right part of A1 and A2 formulas.
4. For the harmful substances, single TLVC of which are not established yet, ten times the average 24-hour TLVC may be temporarily used instead.
5. If there is a background concentration (C_f) in the ambient air, C_m in the formula (A1) above must be replaced by $C_m + C_f$, and $C_{m.1}, C_{m.2} \dots C_{m.n}$ in the formula (A2) must be replaced by $C_{m.1} + C_{f.1}, C_{m.2} + C_{f.2} \dots C_{m.n} + C_{f.n}$.
6. When determining TLVE for operating enterprises and for those under reconstruction, C_f must be replaced by $C'f$, which is the background concentration, and which does not contain the share of the enterprise in question.

$$C'f = C_f \left(1 - 0.4 \frac{C_m}{C_f}\right), \text{ when } C_m \leq 2C_f \quad (\text{A3})$$

$$C'f = 0.2C_f, \text{ when } C_m > 2C_f \quad (\text{A4})$$

7. In the case of determining TLVE for the enterprises under construction:

$$C'f = 0.2C_f \quad (\text{A5})$$

8. The values of background concentration shall be established by the Legal Entity under Public Law (LEPL) - National Environmental Agency of the Ministry of Environment and Natural Resources Protection of Georgia, on the basis of the data of regular observation from the ambient air pollution monitoring stations. In the case of absence of these data, approximate values of background concentration shall be calculated according to the table given below.

Number of population, thousands of persons	Value of background concentration, mg/m ³			
	Nitrogen dioxide	Sulphur dioxide	Carbonic oxide	Dust
250-125	0.03	0.05	1.5	0.2
125-50	0.015	0.05	0.8	0.15
50-10	0.008	0.02	0.4	0.1
<10	0	0	0	0

Calculation of pollution caused by emission of harmful substances from individual point sources of pollution

1. Ceiling level of concentration of harmful substances in the surface layer of ambient air C_m (mg/m³), which is achieved by emission of hot gas and air mixture from round branch pipes of an individual point source of pollution along the X_m (m) distance from this source under unfavourable meteorological conditions, is calculated with the formula:

$$C_m = \frac{AMFmn\eta}{H^2 \sqrt[3]{V_1 \Delta T}} \quad (B1)$$

where:

A – is the atmospheric temperature stratification coefficient (sec²/3.0C^{1/2}, mg/g), for Georgia – $A=200$;

M – the mass of harmful substances emitted into the atmosphere for a certain period of time (g/sec.). It is calculated on the basis of the threshold limit values determined for a given enterprise (processes);

F – is a dimensionless coefficient of the sedimentation rate of harmful substances in the ambient air. For gaseous harmful substances and low-dispersive aerosols (dust, ash) $F=1$; for high dispersion dust and lines - when average operational value of filtration coefficient is >90%, then $F=2$; when the value of this coefficient is within the range of 75% and 90%, then $F=2.5$; when the value of this coefficient is <75% or in the absence of filtration, then $F=3$.

H – the height of the source of emission from the surface of the ground (m).

ΔT – the difference between the temperature of the emitted gas and air mixture and the ambient air temperature (°C).

η – is a dimensionless coefficient of the impact of the relief on the dispersion of the gas and air mixture. For plain areas, where the drop height of the benchmark of the place does not exceed 50 m. per 1 km., $\eta=1$. In other cases η shall be determined on the basis of the cartographic materials, which depict the relief of the site 50 height radius of the pipe away from the enterprise, but not less than 2 km.

V_1 – the consumption of gas and air mixture (m³/sec.), which is calculated with the formula:

$$V_1 = \frac{\pi D^2}{4} \omega_o \quad (B2)$$

where:

D – is the diameter of the branch pipe of the source of emission, (m);

w_o – is an average speed of exit of gas and air mixture from the branch pipe of the source of emission, (m/sec);

m and n – are the dimensionless coefficients of the conditions of exit of air and gas mixture from the branch pipe of the source of emission, which are calculated with the formula:

if $f < 100$, then:

$$m = \frac{1}{0.67 + 0.1 \times \sqrt{f} + 0.34 \times \sqrt[3]{f}} \quad (B3)$$

If $f \geq 100$, then:

$$m = \frac{1.47}{\sqrt[3]{f}} \quad (B4)$$

If $f_e < f < 100$, then m coefficient is calculated with the formula (B3), when $f = f_e$.

if $f < 100$ and $V_m \geq 2$, then: $n = 1$ (B5)

$0.5 \leq V_m < 2$, then: $n = 0.532 V_m^2 - 2.13 V_m + 3.13$ (B6)

$V_m < 0.5$, then: $n = 4.4 V_m$ (B7)

If $f \geq 100$, then n coefficient is calculated with the formulas (6.5-6.7) when $V_m = V'_m$.

The parameters f , V_m , and f_e are calculated with the formulas:

$$f = 1000 \frac{\omega_o^2 D}{H_2 \Delta T} \quad (B8)$$

$$V_m = 0.65 \times \sqrt[3]{\frac{V_1 \Delta T}{H}} \quad (B9)$$

$$V'_m = 1.3 \frac{\omega_o D}{H} \quad (B10)$$

$$f_e = 800 (V'_m)^3 \quad (B11)$$

2. In the case of emission of cold gas and air mixtures from the round branch pipes of individual point sources of pollution (when $f \geq 100$ or $\Delta T \approx 0$ and $V_m \geq 0.5$) the value of C_m is calculated with the formula:

$$C_m = \frac{AMFn\eta}{H^{4/3}} \times \frac{D}{8V_1}, \quad (B12)$$

where:

n is calculated with the formula (6.5-6.7) for the value of $V_m = V'_m$, while if $f < 100$ and $V_m < 0.5$ or $f \geq 100$ and $V'_m < 0.5$ (in the case of minimum limit of dangerous wind speed), then:

$$C_m = \frac{AMFm'\eta}{H^{7/3}}, \quad (B13)$$

where:

$$m' = 2.86m, \text{ when } f < 100, V_m < 0.5 \quad (B14)$$

$$m' = 0.9m, \text{ when } f \geq 100, V_m' < 0.5 \quad (B15)$$

3. The distance from the source of pollution, X_m (m), across which the concentration of harmful substances in the surface layer of ambient air C (mg/m³) reaches maximum value C_m in unfavourable meteorological conditions, is calculated with the formula:

$$X_m = \frac{5-F}{4} dH, \quad (B16)$$

where d - is a dimensionless coefficient, which is calculated with the formula:

$$\text{if } f < 100 \text{ and } V_m \leq 0.5, \text{ then } d = 2.48(1 + 0.28\sqrt[3]{f_e}) \quad (B17)$$

$$0.5 < V_m \leq 2, \text{ then } d = 4.95V_m(1 + 0.28\sqrt[3]{f}) \quad (B18)$$

$$V_m > 2, \text{ then } d = 7\sqrt{V_m}(1 + 0.28\sqrt[3]{f}) \quad (B19)$$

$$\text{if } f > 100 \text{ and } V_m' \leq 0.5, \text{ then } d = 5.7 \quad (B20)$$

$$0.5 < V_m' \leq 2, \text{ then } d = 11.4V_m' \quad (B21)$$

$$V_m' > 2, \text{ then } d = 16\sqrt{V_m'} \quad (B22)$$

4. Dangerous wind speed U_m (m/sec.) at the level of wind direction indicator (10 metres above the ground), where the maximum concentration of harmful substances C_m is achieved, is calculated with the formula:

$$\text{if } f < 100 \text{ and } V_m \leq 0.5, \text{ then } u_m = 0.5 \quad (B23)$$

$$0.5 < V_m \leq 2, \text{ then } u_m = V_m \quad (B24)$$

$$V_m > 2, \text{ then } u_m = V_m(1 + 0.12\sqrt{f}) \quad (B25)$$

$$\text{If } f \geq 100 \text{ and } V_m' \leq 0.5, \text{ then } u_m = 0.5 \quad (B26)$$

$$0.5 < V_m' \leq 2, \text{ then } u_m = u_m' \quad (B27)$$

$$V_m' > 2, \text{ then } u_m = 2.2V_m' \quad (B28)$$

5. In the case of unfavourable meteorological conditions and the wind speed u (m/sec.) (which is different from the dangerous wind speed U_m (m/sec.), the maximum value of concentration of harmful substances in the surface layer of ambient air $C_m.u$ (mg/m³) is calculated with the formula:

$$C_m.u = rC_m, \quad (B29)$$

Where r - is a dimensionless coefficient, which is calculated with the formula:

when $u/u_m \leq 1$, then

$$r = 0.67u/u_m + 1.67(u/u_m)^2 - 1.34(u/u_m)^3 \quad (B30)$$

when $u/u_m > 1$, then

$$r = \frac{3(u/u_m)}{2(u/u_m)^2 - u/u_m + 2} \quad (B31)$$

6. The distance from the source of emission $X_{m.u}$ (m), across which the maximum concentration of harmful substances $C_{m.u}$ (mg/m³) is achieved in the surface layer of ambient air in the case of unfavourable meteorological conditions and wind speed u (m/sec.), is calculated with the formula:

$$X_{m.u} = p X_m, \quad (B32)$$

Where p - is a dimensionless coefficient calculated with the formula:

when $u/u_m \leq 0.25$, then

$$p = 3 \quad (6.33)$$

when $0.25 < u/u_m \leq 1$, then

$$p = 8.43(1 - u/u_m)^5 + 1 \quad (B34)$$

when $u/u_m > 1$, then

$$p = 0.32(u/u_m) + 0.68 \quad (B35)$$

7. The concentration of harmful substances C (mg/m³) in the surface layer of ambient air, which is achieved in the case of a dangerous wind speed u_m (m/sec.) across x (m) distance from the source of emission alongside the torch axle, is calculated with the formula:

$$C = S_1 C_m, \quad (B.36)$$

where S_1 - is a dimensionless coefficient, which is calculated with the formula:

when $x/x_m \leq 1$, then

$$S_1 = 3(x/x_m)^4 - 8(x/x_m)^3 + 6(x/x_m)^2 \quad (B37)$$

when $1 < x/x_m \leq 8$, then

$$S_1 = \frac{1.13}{0.13(x/x_m)^2 + 1} \quad (B38)$$

when $F \leq 1.5$ and $x/x_m > 8$, then

$$S_1 = \frac{x/x_m}{3.58(x/x_m)^2 + 35.2(x/x_m) + 120} \quad (B39)$$

when $F > 1.5$ and $x/x_m > 8$, then

$$S_1 = \frac{1}{0.1(x/x_m)^2 + 2.47(x/x_m) - 17.8} \quad (B40)$$

For the sources of pollution of lower height, where $(2 \leq H < 10)$ $x/x_m < 1$, the value of S_1 in the formula (6.36) must be changed with the value of S_1^H , which is calculated with the formula:

$$S_1^H = 0.125(10 - H) + 0.125(H - 2)S_1 \quad (6.41)$$

8. The concentration of harmful substances C_y (mg/m³) in the surface layer of ambient air, which is achieved in the case of dangerous wind speed u (m/sec.) across y (m) distance from the source of emission in the perpendicular direction from the torch axle, is calculated with the formula:

$$C_y = S_2 C, \quad (6.42)$$

where S_2 - is a dimensionless coefficient, which is calculated with the formula:

$$S_2 = \frac{1}{(1 + 5t_y + 12.8t_y^2 + 17t_y^3 + 45.1t_y^4)^2}, \quad (6.43)$$

where:

$$\text{when } u \leq 5, \text{ then } t_y = \frac{uy^2}{x^2} \quad (6.44)$$

$$\text{when } u > 5, \text{ then } t_y = \frac{5y^2}{x^2} \quad (6.45)$$

9. Maximum concentration of harmful substances $C_{m.x}$ (mg/m³), which is achieved in the case of wind speed $u_{m.x}$ (m/sec.) from the source of emission alongside the torch axle, is calculated with the formula:

$$C_{m.x} = S'_1 C_m, \quad (6.46)$$

where S'_1 - is a dimensionless coefficient, which is calculated with the formula:

when $x/x_m \leq 1$, then

$$S'_1 = 3(x/x_m)^4 - 8(x/x_m)^3 + 6(x/x_m)^2 \quad (6.47)$$

when $1 < x/x_m \leq 8$, then

$$S'_1 = \frac{1.1}{0.1(x/x_m)^2 + 1} \quad (6.48)$$

when $8 < x/x_m \leq 24$, then

$$S'_1 = \frac{2.55}{0.13(x/x_m)^2 + 9} \quad (6.49)$$

when $24 < x/x_m \leq 80$ and $F \leq 1.5$, then

$$S'_1 = \frac{x/x_m}{4.75(x/x_m)^2 - 140(x/x_m) + 1435} \quad (6.50)$$

when $24 < x/x_m \leq 80$ and $F > 1.5$, then

$$S'_1 = \frac{2.26}{0.1(x/x_m)^2 + 7.41(x/x_m) - 160} \quad (6.51)$$

when $x/x_m > 80$ and $F \leq 1.5$, then

$$S'_1 = \frac{x/x_m}{3.58(x/x_m)^2 - 35.2(x/x_m) + 120} \quad (6.52)$$

when $x/x_m > 80$ and $F > 1.5$, then

$$S'_1 = \frac{1}{0.1(x/x_m)^2 + 2.47(x/x_m) - 178} \quad (6.53)$$

The wind speed $u_{m.x}$ is calculated with the formula:

$$um.x=f1um, \quad (6.54)$$

where $f1$ - is a dimensionless coefficient, which is calculated with the formula:

$$\text{when } x/x_m \leq 1, \text{ then } f1=1 \quad (6.55)$$

$$\text{when } 1 < x/x_m \leq 8, \text{ then } f_1 = \frac{0.75 + 0.25(x/x_m)}{(x/9x_m)^9 + 1} \quad (6.56)$$

$$\text{when } 8 < x/x_m \leq 80, \text{ then } f1=0.25 \quad (6.57)$$

$$\text{when } x/x_m \geq 80, \text{ then } f1=1 \quad (6.58)$$

10. In the case of emission of harmful substances from a source of pollution with a rectangular branch pipe, the pollution of the ambient air is calculated with the above formulas, only for the values of the average speed of exit of gas and air mixture into the ambient air (ω_0 , m/sec.), effective diameter of the branch pipe ($D=D_{eff}$, m) and effective exit flow of gas and air mixture into the ambient air for a certain period of time ($V1=V1_{eff}$, m³/sec.):

$$\omega_0 = \frac{V_1}{LB} \quad (6.59)$$

$$D_{eff} = \frac{2LB}{L+B} \quad (6.60)$$

$$V1_{eff} = \frac{\pi D_{ef}^2}{4} \omega_0, \quad (6.61)$$

Where L – is the length of a branch pipe (m), and B – is the width of a branch pipe (m).

11. For each source of pollution the radius of the zone of exposure is calculated as the longest of the two distances $x1$ and $x2$ from the source of pollution, where $x1=10xm$, and $x2$ is the distance from the source of pollution, started for which $C \leq 0.05$ TLVC.

Calculation of pollution caused by emission of harmful substances from a line source of pollution

1. Maximum concentration of harmful substances C_m (mg/m³), which is achieved when the wind's direction is along the line source of pollution with L length (e.g. aerator flashlight) across X_m distance from that source, also the X_m distance, are calculated with the formula:

$$C_m = S_3 C'_m \quad (C1)$$

$$X_m = L/2 + S_4 X'_m, \quad (C2)$$

Where C'_m and X'_m - are deemed equal to the values of Cm and Xm , which correspond with individual point sources of pollution, in the case of the same emission capacity M , D_{eff} diameter of the round branch pipe and $V1_{eff}$ flow of emitted gas and air mixture. Also:

$$D_{eff} = \frac{2LV_1}{L^2 \omega_0 + V_1} \quad (C3)$$

S3 and S4 – are dimensionless coefficients, which are calculated with the formulas:

$$S_3 = \frac{1 + 0.45 \frac{L}{X'_m}}{1 + 0.45 \frac{L}{X'_m} + 0.1 \left(\frac{L}{X'_m} \right)^2} \quad (C4)$$

$$S_4 = \frac{1}{1 + 0.6 \frac{L}{X'_m}} \quad (C5)$$

The dangerous wind speed u_m is calculated with the formula:

$$u_m = u'_m \quad (C6)$$

2. The concentration of harmful substances C (mg/m³) which is achieved across X_m distance from the line source of pollution, in the case of the wind speed u_m (m/sec.) alongside this source, is calculated with the formula:

$$C = (S'_5 - S''_5) X'_m C'_m / L, \quad (C7)$$

When $u \neq u_m$, the value of C is calculated with the formula:

$$C = pr (S'_5 - S''_5) X'_m C'_m / L, \quad (C8)$$

Where r and p are calculated with the formulas (6.30-6.35) for the value of u/u'_m , while S'_5 and S''_5 - accordingly for the values of $\frac{2X + L}{2pX'_m}$ and $\frac{2X - L}{2pX'_m}$.

C'_m and X'_m are calculated according to paragraphs 1 and 6 of this article.

3. Maximum concentration of harmful substances C_m (mg/m³) when the wind speed is along the direction of the line source of pollution u'_m (m/sec.), is calculated with the formula:

$$C_m = \varepsilon_1 C'_m, \quad (C9)$$

where ε_1 - is a dimensionless coefficient, which is calculated with the formulas:

$$\text{When } a \leq 0.255, \text{ then } \varepsilon_1 = 0.923a \quad (C10)$$

$$\text{When } 0.225 < a \leq 2.32, \text{ then } \varepsilon_1 = 1.13a^2 / (a + 0.3)^2 \quad (C11)$$

$$\text{When } a > 2.32, \text{ then } \varepsilon_1 = a^2 / (a^2 + 0.7), \quad (C12)$$

where:

$$a = \frac{X'_m}{L \sqrt{u'_m}}, \text{ when } u'_m \leq 5 \quad (C13)$$

$$a = 45 \frac{X'_m}{L}, \text{ when } u'_m > 5 \quad (C14)$$

The distance from the line source of pollution X_m (m), across which the maximum concentration of harmful substances C_m (mg/m³) is achieved, is calculated with the formula:

$$X_m = \varepsilon_2 X'_m, \quad (C15)$$

where:

$$\text{When } a \leq 0.25, \text{ then } \varepsilon_2 = 3 \quad (C16)$$

$$\text{When } 0.25 < a \leq 2.25, \text{ then } \varepsilon_2 = \frac{1.5}{\sqrt{a}} \quad (C17)$$

$$\text{When } a > 2.25, \text{ then } \varepsilon_2 = 1 \quad (C18)$$

4. The concentration of harmful substances C (mg/m³), which is achieved across X distance from the centre of the line source of pollution when the wind speed u (m/sec.) is perpendicular to the longitudinal axis of this source, is calculated with the formula:

$$C = S_1 S_6 r C'_m \quad (C19)$$

The concentration of harmful substances C_y (mg/m³), achieved across y (m) distance from the axle of the torch, is calculated with the formula:

$$C_y = \frac{r S_1}{2} \left[\left(1 + \frac{2y}{L} \right) S'_6 + \left(1 - \frac{2y}{L} \right) S''_6 \right] C'_m, \quad (C20)$$

where S_1 - is a dimensionless coefficient, which is calculated with the formulas (B37-B41) for the value of $x / p x'_m$:

S_6 , S'_6 , S''_6 – are dimensionless coefficients, which are calculated with the formula (C21), depending on the values of L (m), $(2y+L)$ (m) and $(2y-L)$ (m), respectively:

$$S_6 = 0.57g \left[1 - \frac{1}{\left(1 + \frac{0.44}{g} + \frac{0.58}{g^2} + \frac{0.49}{g^4} \right)^4} \right], \quad (C21)$$

where:

$$\text{when } u \leq 5, \text{ then } g = \frac{x}{L} \sqrt{u} \quad (C22)$$

$$\text{when } u > 5, \text{ then } g = 0.45 \frac{x}{L} \quad (C23)$$

If $g > 6.74$, the value of S_6 is equal to 1.

5. In the case of any direction of the wind in relation to the line source of pollution (aerator flashlight), this source is conditionally considered as the group of N similar, equally remote point sources. For each of those point sources the maximum concentration of harmful substances C_m (mg/m³), the corresponding X_m (m) distance and dangerous wind speed u_m (m/sec.) is calculated with the formula:

$$C_m = C'_m / N \quad (C24)$$

$$X_m = X'_m \quad (C25)$$

$$u_m = u'_m, \quad (C26)$$

Where N – is the number of similar, equally remote point sources of pollution, which is calculated with the formula:

$$N = \frac{5L\sqrt{u}}{X}, \quad (C27)$$

where:

X - is the shortest distance from the aerator flashlight to the reference point of the site (m);

y - is the reference wind speed.

6. For similar, equally remote point sources of pollution, the concentration of harmful substances in the surface layer of ambient air is calculated with the same formulas, as for aerator flashlights, however for the calculation of the values of C'_m , X'_m and u'_m the average values of D and $V1$ will be used instead of the values of $Deff$ and $V1.eff$, as it was characteristic of the individual point sources of pollution.