Supply Ventilation and Prevention of Carbon Monoxide (II) Ingress into Building Premises

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Abstract. The article contains the relationships of carbon monoxide (II) concentration versus height-above-ground near buildings derived based on results of studies. The results of studies are crucial in preventing external pollutants ingress into a ventilation system. Being generated by external emission sources, such as motor vehicles and city heating plants, carbon monoxide (II) enters the premises during operation of a supply ventilation system. Fresh air nomographic charts were drawn to select the height of a fresh air intake into the ventilation system. Nomographic charts take into account external sources. The selected emission sources are located at various levels above ground relative to the building. The recommendations allow designing supply ventilation taking into account the quality of ambient air through the whole building height.

1. Introduction
When using a mechanical ventilation system to supply fresh air from outside, the city’s ambient air can worsen the quality of air inside the premises [1]. Such ventilation system is used not only in administrative and public buildings, but also in residential houses of many large cities of Russia. Tyumen city is not an exception.

Currently there is no clear answer as to how to select the ventilation place to supply fresh air from outside of a building inside a building’s premises in a city [2-8]. In the currently applicable normative documents, particularly in SNiP 41-01-2003 it is written, that the height of intake of outside air must be not less than 2 m. At the same time it is recommended to place the fresh air intake at the areas where the least polluted ambient air is – away from streets with heavy traffic, away from heating plants, within a block of houses, in a greenery area. In cases when it is impossible to arrange intake of fresh air at 2 meter height, it is usually placed at the roof of a building, where the quality of air is not controlled. At a designing stage of ventilation it impossible to predict air quality above 2 meters along the whole height of the building. The concentration of all pollutants are measured not higher than 2 m above ground. Besides, a filter of a fresh air intake plenum is not designed to clean out emissions of contaminating gases [9-12].

Therefore, selection of a place of a fresh air ventilation intake in a building in city settings is not yet substantiated. It is thus necessary to have a detailed justification for selecting a place of the fresh air ventilation intake for building premises in a city taking into account external sources of environment pollution [13].
2. Formulation of the problem
The objective of this study is to determine an optimum place of an ambient air intake of a ventilation system in relation to the quality of ambient air. With this in mind, it is necessary to assess degree of ambient air pollution throughout the whole height of a building.

Carbon monoxide (II) was selected as an external pollutant to resolve the tasks. Carbon monoxide (II) is an abundant pollutant of air. Carbon monoxide (II) CO is always generated when various types of fuel are burnt in the presence of such quantities of air which are insufficient for synthesis of carbon dioxide CO2. In addition to this, carbon monoxide (II) can be removed from the room only by ventilation [14-20].

The subjects of study were multistoried buildings. The external pollutants were both moveable and stationary (single point).

Firstly, for field studies, there were selected buildings, located near crossroads with varying density of traffic: above 2000 vehicles per hour; from 1000 to 2000 vehicles per hour; from 600 to 1000 vehicles per hour; from 500 to 600 vehicles per hour. The studies were conducted at adverse wind speeds coming from the moveable sources (1–2 m/sec.).

Secondly, there were selected buildings, located in the areas of operation of small-sized and middle-sized heating plants. Varying heights of heating plants’ stacks were selected relative to the height of a building itself: 2 times higher, 0,5 times lower and a height equal to the building height. The buildings were located in the effective area of these heating plants, at various distances from the source. The heating plants studies were conducted at adverse wind speeds coming from the stationary sources (5–6 m/sec.).

Concentration levels of carbon monoxide (II) in ambient air were measured throughout the whole height of a building. The total number of observation posts was 354 at the outline of the urban area within the city of Tyumen. The period of studies was 5 years. During field trips to observation points 20 samples were taken from each point.

The boundaries of aerodynamic shades were outlined for the buildings under study: windward (I) and leeward (II) (Figure 1). Please follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented.

![Figure 1. Boundaries of aerodynamic shades of a building: I – windward ; II – leeward ; III – outside of aerodynamic shade](image)

Within aerodynamic shades secondary recirculation air currents appear, with wind velocities reaching zero and intense turbulent mixing occurring. This fact results in buildup of gases throughout the whole height of the building.

3. Solution of the problem
Measuring results of CO concentration throughout the height of the buildings was represented as a function of dimensionless length (h/H, where h is the height above ground, m; H – height of a building, m). The concentration by height is represented as dimensionless value relative to the
maximum concentration \((c/c_{\text{max}})\), where \(c\) is maximum concentration throughout the height of a building, mg/m\(^3\); \(c_{\text{max}}\) is the concentration at a specific height, mg/m\(^3\).

The processing of experiment data allowed to derive relationships of dimensionless CO concentration values versus height of the building facade corresponding to various levels of emission sources: 1. above building \(H_s>H\ (H_s=2H)\); 2. below building \(-H_s<H\ (H_s=0.5H)\); 3. equal to the height of the building \(H_s=H\), where \(H_s\) is a source height, m; \(H\) is a building height, m. Tables 1–2 show relationships of pollutant sources \(H_s=0.5H\) and \(H_s=H\) on the windward side of the buildings.

**Table 1.** Relationships of CO concentration versus stack height located 0.5 times below the building.

| \(R/H_s\) | \(c/c_{\text{max}}\) Windward side |
|----------|-----------------------------------|
| 5        | \(-2.38 \left(\frac{h}{H}\right)^2 + 2.34 \left(\frac{h}{H}\right) + 0.06\) |
| 10       | \(-1.70 \left(\frac{h}{H}\right)^2 + 2.02 \left(\frac{h}{H}\right) + 0.04\) |
| 15       | \(-0.29 \left(\frac{h}{H}\right)^2 + 0.72 \left(\frac{h}{H}\right) + 0.11\) |
| 20       | \(-0.95 \left(\frac{h}{H}\right)^2 + 0.78 \left(\frac{h}{H}\right) + 0.26\) |

\(R\) – distance from the source mouth to the building, m; \(H_s\) – source height, m; \(H\) – building height, m; \(h\) – height above ground, m.

**Table 2.** Relationships of CO concentration versus stack height located at the same level as the building height.

| \(R/H_s\) | \(c/c_{\text{max}}\) Windward side |
|----------|-----------------------------------|
| 5        | \(-2.08 \left(\frac{h}{H}\right)^2 + 1.78 \left(\frac{h}{H}\right) + 0.36\) |
| 10       | \(-1.56 \left(\frac{h}{H}\right)^2 + 2.20 \left(\frac{h}{H}\right) + 0.25\) |
| 15       | \(-1.72 \left(\frac{h}{H}\right)^2 + 1.95 \left(\frac{h}{H}\right) + 0.29\) |
| 20       | \(-1.43 \left(\frac{h}{H}\right)^2 + 1.38 \left(\frac{h}{H}\right) + 0.39\) |

\(R\) – distance from the source mouth to the building, m; \(H_s\) – source height, m; \(H\) – building height, m; \(h\) – height above ground, m.

The carried out experiment showed correlation between CO concentration and the stack height depending on the height of the building itself \((H)\), as well as a relationship between the distance of the building to the stack – \(R\).
Similar relationships were acquired for motor roads with varying traffic intensity, Table 3.

Table 3. Calculation of dimensionless CO concentration versus the whole height of a building in relation to the motor roads with varying traffic intensity.

| Traffic intensity (vehicles/h) | Windward side |
|-------------------------------|---------------|
| Up to 500 to 600              | \( \frac{c}{c_{\text{max}}} = 0.0012 \left( \frac{h}{H} \right)^2 - 0.054 \left( \frac{h}{H} \right) + 0.135 \) |
| From 600 to 1000              | \( \frac{c}{c_{\text{max}}} = 0.0032 \left( \frac{h}{H} \right)^2 - 0.144 \left( \frac{h}{H} \right) + 0.433 \) |
| From 1000 to 2000             | \( \frac{c}{c_{\text{max}}} = 0.0055 \left( \frac{h}{H} \right)^2 - 0.356 \left( \frac{h}{H} \right) + 0.792 \) |

Figure 2. Nomographic charts for determining optimum height of fresh air intake from the source: the height of which is equal to the height of a building, where \( H_s \) – source height, m; \( R \) – distance from the mouth of a source to the building, m; \( h \) – fresh air intake height above ground, m; \( C \) – carbon monoxide (II) concentration, mg/m³.

Figure 3. Nomographic charts for determining optimum height of fresh air intake from the source: the height of which is 2 times higher than the height of a building.

Figure 4. Nomographic charts for determining optimum height of fresh air intake from the source: the height of which is 0.5 times below the height of the building.
In order to select optimum height of fresh air intake for buildings with varying number of floors when designing a ventilation system it is convenient to use the resulting nomographic charts (Figure 2–4).

When designing a fresh air ventilation system it is recommended to use the nomographic charts of Figure 2–Figure 4 in the following way:

1. Determine the pollutant source height \( H_s \) relative to the height of a building \( H \): 
   - \( H_s = 2H \);
   - \( H_s = H \);
   - \( H_s = 0,5H \);

2. Based on the city plan determine the distance from the pollutant source to the building \( \text{R} \), m;

3. Find a relationship between the distance of the building from the source, to the height of the source: \( \text{R}/H_s \);

4. Using the nomographic chart determine CO concentration throughout the whole height of the building at a height above ground \( h \) and the distance \( \text{R}/H_s \);

5. On the nomographic chart select optimum height of the fresh air intake taking into account maximum allowable concentration of CO in the premises.

Additionally, when locating buildings near motor roads with high traffic density the place of fresh air intake placement is determined based on the nomographic chart, presented of Figure 5.

The use of nomographic chart presented on Figure 5 when designing a ventilation system in a building, allows to determine minimum CO concentration in any point throughout the height of a building relative to the crossroads with varying traffic intensity. With traffic intensity of 1000–2000 vehicles/hour fresh air intake is arranged at levels above 0,24\( H \) meters, where \( H \) is the height of a building, m; with traffic intensity above 2000 vehicles/hour fresh air intake is arranged above 0,56\( H \) meters. For traffic intensity of 600–1000 vehicles/hour if the limits are not exceeded, then the fresh air intake shall be arranged as per the nomographic chart, from the height equal to height of a building \( H \), since at this level the CO concentration is minimal.

The suggested nomographic charts (Figure 2–5) and relationships (Tables 1–3) have been designed for the windward side of a building. Based on results of field studies the results of leeward side of a building must be reduced by 15%.

4. Summary
1. Relationships between carbon monoxide (II) concentration levels and the height above ground as well as relationships between the height of the building itself versus the quality of ambient air (varying emission heights) have been developed.
2. Nomographic charts are proposed for selecting the optimum location of fresh air intake of a supply ventilation of a building taking into account the quality of outside air throughout the whole height of the building.

3. Nomographic charts and calculated relationships have been implemented at CJSC «Tyumen Institute for Design of Agro-Industrial Facilities», Design Institute for construction of administrative high-rise buildings taking into account transport motor roads (Melnikaite Street, city of Tyumen). Intensity of traffic at the motor road is above 2000 vehicles/hour. These recommendations allowed to select the optimum location of a fresh air intake of a building supply ventilation.

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