EVALUATION OF CARBON MONOXIDE POLLUTION IN BUCHAREST AND POTENTIAL RISKS FOR HUMAN HEALTH. PART I

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Abstract. The quality of the atmosphere is considered to be the key factor in an environment monitoring network, a pollutant atmosphere always being associated with short, medium and long-time effects. On the short and medium scale, it may have effects on human health, on ecosystems and can produce economical damages. On long-term, the substances emitted in the atmosphere are the cause of actual environmental burdens as: world warming, acid rains, ozone layer depletion and so on. Among these substances, carbon monoxide represents one of the most important atmospheric pollutants. Carbon monoxide is of particular interest and importance as many deaths and hospital admissions can be directly attributed to accidental domestic CO poisoning. It is especially dangerous since due to its properties (odourless, tasteless and colourless gas), carbon monoxide continues to kill tens and even thousands people per year, via accidental inhalations. Therefore, the main objective of this investigation is to analyse the levels of atmospheric carbon monoxide concentration in the city centre of Bucharest (the monitoring stations were placed in ‘Cercul Militar’ and ‘Mihai Bravu’ zones) and compared them with CO concentration from outside of the city: in north of Bucharest (the Balotesti county) and south-east of Bucharest (the Magurele county). All the concentrations were evaluated in relation to the maximum concentration level in accordance to the legislation requirements on environmental air quality. By monitoring the CO concentration during three-year period (March 2004–March 2007), it has been observed that in both city center zones, the accepted long time exposure level (2 mg/m$^3$) or even short time exposure level (6 mg/m$^3$, at half an hour) were exceeding the maximum concentration level, regulated by the Romanian Standard (STAS 12574/87).

Keywords: air quality, carbon monoxide pollution, long/short time exposure level, health effects.

AIMS AND BACKGROUND

The carbon monoxide is a common by-product coming from combustion of any kind of fuel. The majority of equipments with fuel burning systems (coal, wood, natural gases, propane and oils), even they are adequately installed and preserved they give rise to some amounts of carbon monoxide$^{1,2}$. By-products of burning are usual released outdoor, when a faulty device or unusual conditions exists (interruption of ventilation process, inadequate supply oxygen). The result is that CO may be

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vented into atmosphere where people are present. Heated houses using inadequately or damaged burning installations (stove heating, hot water heaters) are the main indoor air polluting source and have direct involvement on human health\textsuperscript{2–4}, due to the fact that CO production may reach very fast dangerous levels.

For outdoor air, the sources which release carbon monoxide are: the existence of city incinerators that produce incomplete combustions from any type of wastes (hospital incinerators, installation for wastes destruction, etc.), industrial area (metallurgical units and power plants), a large number of heated houses equipped with low height chimneys for gas releasing, inappropriate for carbon monoxide release at sufficient height (where CO may be easy transformed in CO\textsubscript{2}), during forest burning, coal, kerosene, gasoline, tobacco smoke and so on\textsuperscript{1,2,4–7}. However, the main source which releases high quantities of CO in the atmosphere is incomplete burning of fuel from gases evacuated by vehicles\textsuperscript{4–6}.

In Romania, in urban area, intense and crowded traffic, dust and gases from vehicle engine stagnation during a long period of time determine in this area the CO concentration to be much amplified. The traffic problem is the same in many cities of the country where are inappropriate conditions and inadequate roads, like insufficient and inefficient number of roads for a large number of vehicles, which is ongoing growth\textsuperscript{3}. Fortunately, international standards which are more and more severe with CO emission in air, forced the constructors to modernise the vehicle engines and to improve the burning process. This improvement together with a periodic control of its functionality, results in a considerable reduction of the CO concentration in the air, but not sufficient. To date, in Romania, these requirements and standards do not rich the international requested level, due to large number of old and high tonnage vehicles running in disagreement to legislation, leading to an ambient CO concentration which in most of the cases exceeds the maximum admitted concentration level.

The dangerous levels of carbon monoxide for humans determined international competent forum to adopt a federal low according to the admitted maximum concentrations standards in ambient environment. In Romania, the standard which regulates the admitted maximum concentration in air is STAS 12574/87 ‘Air from pollutant zones – quality conditions” (admitted maximum concentration for a short time exposure – 1/2 h is 6.0 mg/m\textsuperscript{3} and for a long-time exposure, 2.0 mg/m\textsuperscript{3}) (Ref. 8).

The effects of high carbon monoxide concentrations on human organism are difficult to be anticipated due to the fact that in urban crowd/agglomeration – in many situations – the recommended concentrations are exceeding and the people are exposed during different periods of time and in a repeated mode at carbon monoxide concentrations without determining specific chronic health effects. Carbon monoxide poisoning may be difficult to be diagnosed because many of its symptoms are similar to the flue, and may include headache, drowsiness and
general weakness. At the same time, it is difficult to differentiate the effects induced by high carbon monoxide concentrations exposure from those caused by other atmospheric pollutants\textsuperscript{2,9}.

The harmful effects of CO inhalation depend on the following factors: concentration of CO in the air, length of time of exposure to CO gas, the health state, age, sex and weight of the individual being exposed\textsuperscript{9–11}. The secondary effects of CO on human health are varied, but the most serious effect results from carboxyhemoglobin formation (COHb) (Refs 12 and 13): CO enters sang flux where is attached to hemoglobin with carboxyhemoglobin formation – a product responsible for serious intoxication and even death.

There are a large number of publications on health effects produced after carbon monoxide exposure\textsuperscript{9–12}. It is also probable that in some houses CO levels routinely occur and persist that might possibly give rise to chronic health effects, particularly among sensitive groups (pregnant mothers, the fetus, children, the elderly and individuals suffering from anemia and other diseases that restrict oxygen transport). Significant symptoms are generally experienced, even among normal healthy individuals who were exposed to high CO concentrations enough to produce COHb levels of about \( \sim 20\% \). A great importance would be assessed to CO concentrations producing COHb levels above 10\%, especially in sensitive individuals\textsuperscript{12,13}. Although there is limited information on health effects produced as a result of ambient CO level exposure – usual founded in house – nevertheless the risk of adverse effects on healthy human still exists.

The International Agency of Environmental Protection (EPA, U.S. Environmental Protection Agency) published the causal correlations established between cigarette smoke exposure and the hearth dieses as nasal sinus cancer at adults, and in the case of children – the problem of death syndrome, asthma and ear dieses\textsuperscript{7}. Therefore, it must not ignore the exposure to cigarette smoke: the women during pregnancy who are exposed to cigarette smoke have tendency to born children with low weight and may appear serious effects (asthma) and the children are much inclined to infections in nose, neck and chest.

Therefore, taking into consideration all these aspects it is prudent and even necessary to continue and to encourage the measures which minimise the CO levels in atmosphere and it is essential to grow up the knowledge on CO intoxication symptomology. The medical symptoms of carbon monoxide intoxication include\textsuperscript{9,10}:

- 200 ppm CO: slight headache, fatigue, dizziness, nausea, after 2–3 h;
- 400 ppm CO: frontal headache within 1–2 h; life threatening after 3 h;
- 800 ppm: dizziness, nausea and convulsion within 45 min; unconsciousness within 2 h and death within 2 to 3 h;
- 1600 ppm CO: headache, dizziness and nausea within 20 minutes; death within 1 h;
• 3200 ppm CO: headache, dizziness and nausea within 5 to 10 min; death within 30 min;
• 6400 ppm CO: headache, dizziness and nausea within 1 to 2 min; death within 10 to 15 min;
• 12 800 ppm CO: death within 1 to 3 min.

The main objective of this investigation is to analyse the levels of atmospheric CO concentrations in Bucharest and its surroundings and to compare them with maximum concentration level (STAS 12574/87), in accordance to the legislation requirements on environmental air quality.

In Bucharest and other country zones there are many air monitoring stations placed in key locations in order to monitor the main pollutants concentrations that might result from different emissions and constitute a potential risk to humans health. In this study it has been considered an evaluation of carbon monoxide levels in 4 monitoring points from Bucharest (Fig. 1). These locations have been randomly chosen: two of them were placed in the city centre (‘Cercul Militar’ and ‘Mihai Bravu’ zones) and the other two are placed out of the city, at ~25 km north of Bucharest (the Balotesti county) and ~15 km south-east of Bucharest (the Magurele county).

Fig. 1. Schematic map of Bucharest and surrounding showing the 4 analysed zones

This paper presents a case study regarding the carbon monoxide pollution in the city centre of Bucharest. This report is the result of cooperation between the institution with responsibilities in environmental domain at local level (Local Environmental Agency, Bucharest) and University Polytechnica of Bucharest. In order to establish the evolution of air quality, during March 2004–March 2007 period, a number of 24 samples per day (hourly) have been sampled and analysed, showing in this way the carbon monoxide pollution in Bucharest atmosphere.
RESULTS AND DISCUSSION

The investigation of carbon monoxide pollution in the city centre of Bucharest was monitored by measuring the CO concentrations during three-year period (March 2004–March 2007). The results were analysed by representation of $C_{CO} = f(\text{month, day})$ and $C_{CO} = f(\text{day, hour})$ variations. As seen from Figs 2, 3 and 6–15, in the city centre of Bucharest (‘Mihai Bravu’ and ‘Cercul Militar’ zones), carbon monoxide concentrations in the most cases are above the maximum admitted concentration for a long-time exposure (2 mg/m$^3$, STAS 12574/87) and sometimes those for a short-time exposure (6 mg/m$^3$, for $\frac{1}{2}$ h, STAS 12574/87).

**Fig. 2.** Variation of CO monthly concentration average during March 2004 – March 2007 period, in the ‘Mihai Bravu’ zone

**Fig. 3.** Variation of CO monthly concentration average during March 2004 – March 2007 period, in the ‘Cercul Militar’ zone

On the contrary, the monitoring of CO concentrations in both extra-urban counties (Balotesti and Magurele) established the existence of a low pollution level, sometimes not existing at all (with two exceptions, as seen later), monthly
CO concentration average being < 0.8 mg/m³ (Figs 4 and 5), means that in these counties there was no a real danger on human health.

Fig. 4. Variation of CO monthly concentration average during March 2004 – March 2007 period, in the Balotesti county

At the first sight, analysing the CO concentration monthly average \( (C_{CO} = f(\text{month, day})) \) in the ‘Mihai Bravu’ zone, it may be observed that during 2004–2005 the CO concentrations were situated below maximum concentration level (MCL) for a long exposure (being \( \leq 1.5 \text{ mg/m}^3 \)); nevertheless, what is alarming is the fact that in October 2006, the values are exceeding this threshold, with a maximum in December of about 4.9 mg/m³ (Fig. 1). Similar values, slightly lower, are recorded in the first three months of 2007, in ‘Mihai Bravu’ zone (\( \sim 3 \text{ mg/m}^3 \)).

In ‘Cercul Militar’ zone, the CO levels in winter months had exceeding MCL for a long exposure during 2004–2006, and in 2007 the values for January and February had exceeding MCL for a short exposure (Fig. 2). These periodical exceeding leads to the conclusion that there was a serious hazardous risk on people health passing through this.

Fig. 5. Variation of CO monthly concentration average during March 2004 – March 2007 period, in the Magurele county
Further, based on carbon monoxide concentration daily average ($C_{CO} = f(\text{day}, \text{hour})$), it was observed that there were days and hours (usually, winter months) when alarming levels have been reached. From this reason it focused on those months in which CO concentrations were above maximum concentration level, for short-period exposure, 6 mg/m$^3$ (Figs 6–15) – dangerous for human health.

![Fig. 6. Variation of daily CO concentration average in ‘Mihai Bravu’ zone: October 2004 (a) and November 2004 (b)](image)

2004 year. In ‘Mihai Bravu’ zone, in March and April, values above the maximum concentration level for a long-time exposure (2 mg/m$^3$, STAS 125741/87) have been recorded, maximum CO levels being observed in morning hours (8:00–11:00) and in the evening (20:00–24:00).

In the next period (May – August) in ‘Mihai Bravu’ zone, the CO concentrations were over of MCL for a long-time exposure, but the values were kept less than 4.5 mg/m$^3$ (May – June), and < 3 mg/m$^3$ (July – August). From September, the CO concentrations began to increase and reached values of about 5 mg/m$^3$, in this way in the second part of October (Fig. 6a) the CO concentrations were exceeding the maximum admitted level for a short exposure (6 mg/m$^3$ at 1/2 h, STAS 125741/87), with values of about 6–7 mg/m$^3$. In November and December, the values of carbon monoxide concentrations were also above MCL, reaching values of about 8 mg/m$^3$, at the beginning and the end of November (Fig. 6b) and in the second part of December.

In ‘Cercul Militar’ zone in 2004 were recorded alarming concentrations of carbon monoxide, thus in March and April – in some days – daily averages of carbon monoxide were close to admitted maximum concentration for a short exposure, and at the end of April they were much above MCL (registered values were more than 10 mg/m$^3$). Similar values were recorded in June – September period, with a maximum of about ~ 9.5 mg/m$^3$ in September (Fig. 7a).
Alarming concentrations of carbon monoxide were observed in October – December, with maxima of about 18, 10 and 16 mg/m$^3$, respectively (Figs 7 and 8), much higher than the admitted maximum concentration for a short-time exposure (6 mg/m$^3$, 1/2 h).

**Fig. 7.** Variation of daily CO concentration average in ‘Cercul Militar’ zone: September 2004 ($a$) and October 2004 ($b$)

**Fig. 8.** Variation of daily CO concentration average in ‘Cercul Militar’ zone: November 2004 ($a$) and December 2004 ($b$)

As expected in both counties situated near Bucharest (Balotesti and Magurele), the carbon monoxide daily average not exceeding 1.5 mg/m$^3$, with one exception in Magurele where at the end of July the values were between 2 and 4 mg/m$^3$, but monthly concentration averages were significantly kept less than in the city centre of Bucharest (Figs 4 and 6).

**2005 year.** In ‘Mihai Bravu’ zone, MCL was exceeding at the end of February (in the morning hours), with values of about ~ 7 mg/m$^3$. In April there was a decreas-
ing of CO concentrations (< 1 mg/m³), with one exception – at the end of month – when the values were close to 4 mg/m³. In the next months values above MCL have been periodically recorded, but for a long-time exposure (2 mg/m³), with priority at the end of week and in afternoon hours.

In both summer months (July and August) the carbon monoxide concentrations did not exceeded a daily average of about 3 mg/m³. As expected in September, the values of carbon monoxide began to increase with a maxim of about 5–6 mg/m³ at the end of September (over 20:00 hour). In October there were two critical situations in which the maxima of about ~ 8 and respectively 10 mg/m³ were registered in some days (Fig. 9a). In November–December period, the CO concentrations were in a slow decrease, but they were also higher than the maximum concentration level for a short exposure, the values of daily average being between 6 and 8 mg/m³ (Fig. 9b).

![Figure 9](image)

**Fig. 9.** Variation of daily CO concentration average in ‘Mihai Bravu’ zone: October 2005 (a) and November 2005 (b)

In ‘Cercul Militar’ zone, the values drop down at the beginning of 2005, compared to 2004, but they are still in a dangerous range, about 6 mg/m³; in some days in February and in March we could find values as 7–8 mg/m³. During summer, from May to August, CO values drop down significantly, below MCL for a short exposure (< 4.5 mg/m³), but above MCL for long period exposure. From September (with exception of November) CO concentrations recorded in ‘Cercul Militar’ zone rise up above the admitted limit (Fig. 10a), and reached a maximum at the beginning of December of about 12 mg/m³ (Fig. 10b).
In the first months of 2005, in both places outside Bucharest, the daily concentration generally remained less than 1.8 mg/m$^3$ with exception for February and August when there were some daily concentrations as 3 mg/m$^3$, respectively $>2$ mg/m$^3$ in Balotesti, and $<2$ mg/m$^3$ in Magurele (January, March, April, June, August and September). Therefore, there were days when the long period concentration level had been reached, but the monthly average of carbon monoxide concentration in 2005 was not above 0.8 mg/m$^3$ (Figs 4 and 5).

2006 year. In the first two months of 2006, in ‘Mihai Bravu’ zone, the average CO concentrations in some days were above MCL for a short exposure period, with values $\geq6$ mg/m$^3$. In April, CO values drop down under 6 mg/m$^3$, but in May and June the values are going down below 3 mg/m$^3$. In two summer months (July and August), the concentration dropped down below 2.5 mg/m$^3$, with a little exception at the middle of August when was recorded a daily average of 4 mg/m$^3$. Since the end of October (Fig. 11), the CO concentrations exceeded the admitted limit, reaching values up to 9 mg/m$^3$, and in November (Fig. 12$a$) was reached a maximum which exceeded 5 times the maximum admitted limit ($\sim$ 31 mg/m$^3$), the other values being high as well: 10 mg/m$^3$ (at the end of the month) and $\sim$ 20 mg/m$^3$ (in the first week of the month). In December the values are high, with an average of about 8 mg/m$^3$, and in the week the values reached 12 mg/m$^3$ (Fig. 12$b$).
In 2006 in ‘Cercul Militar’ zone, in the first three months of the year there where periods of time when CO concentration exceeded again MCL (Fig. 13), with maximum values in some days in February and March (8, respectively 10.2 mg/m³). Between April–September, daily values start dropping down below 6 mg/m³, but at the end of October (Fig. 14) the values start rising again, exceeding in some periods of time the maximum admitted concentration (e.g. in the last day of the month, the CO concentration reached 10 mg/m³).
In the first four months of 2006, in both locations outside Bucharest, the daily CO concentrations did no reach 1.5 mg/m³ with one exception (in Magurele) where at the beginning of March were recorded values between 2–2.8 mg/m³. The values maintained somehow similar also in the next period (May–December), with small exceptions: in Balotesti, at the beginning of July, the 2 mg/m³ stage has been exceeded and between 10–15th of October the concentrations exceeded admitted maximum level for a short exposure, reaching a value of 10 mg/m³; in Magurele (in October–December), the values were situated between 2–3.6 mg/m³.

2007 year. At beginning of 2007 year, CO concentrations in ‘Mihai Bravu’ zone decreased (Fig. 15, a and b), with maximum in some periods of time when MCL
was reached (≤ 6 mg/m$^3$), but in March carbon monoxide concentrations have been higher than MCL (with a maximum of 8 mg/m$^3$ at the end of month).

Unfortunately, in 15 January–15 February 2007 period (in ‘Cercul Militar’ zone), the carbon monoxide concentrations were constantly maintained at high values (12–13 mg/m$^3$), much above maximum concentration admitted for a short-time exposure.

In the Balotesti county, the CO concentrations decreased at the beginning of the year, with values less than 1.8 mg/m$^3$ (Fig. 4). In the Magurele county the monthly averages were less than 2 mg/m$^3$, but in the second part of January, the maximum concentration was reached for a short-time exposure (6 g/m$^3$). In March, the carbon monoxide concentrations were <1.8 mg/m$^3$ (Fig. 5).

**CONCLUSIONS**

The carbon monoxide concentrations monitored during three-year period of time (March 2004–March 2007) had as purpose to highlight the potential risks on human health caused by high levels of carbon monoxide in Bucharest. For a better evidence of high CO concentrations, the concentrations monitored in two central areas of Bucharest (‘Mihai Bravu’ and ‘Cercul Militar’ zones) were compared with other counties near Bucharest (Balotesti – in the north and Magurele – in south-west). The results recorded after monitoring the CO concentration in air in these 4 locations revealed the following aspects:

- CO is a gas pollutant locally produced because its air concentrations are in average the same in the centre of Bucharest (at the two locations), which are different out of Bucharest (the Balotesti and Magurele counties) where CO concentrations are lower, generally below the maximum admitted concentration on
long/short-time exposure, with two exceptions: in the Magurele county, in the second half of January had reached the maximum admitted concentration for a short-time exposure (6 mg/m$^3$); in the Balotesti county, in October was reached 10 mg/m$^3$.

- High values of CO concentrations were detected in the two central locations of Bucharest where the traffic is the most intensive. In ‘Cercul Militar’ zone, in 2006, in seven out of twelve months monitored, the average monthly concentration was higher than the maximum admitted limit on a long period of time (2 mg/m$^3$, STAS 12574/87). Most of the values were recorded in the first three months of 2007, in samples from ‘Cercul Militar’ area (daily average concentrations >12 mg/m$^3$).

- Even the CO concentration monthly average from atmosphere was not exceeding the maximum limits for a short period of time (6 mg/m$^3$), however – with exception of summer months – the maximum admitted concentration for a long-time exposure (2 mg/m$^3$) was reached and in the most cases exceeded during entire period analysed (for example, ‘Cercul Militar’ zone). Moreover, since there were consecutive hours and even days in which CO concentrations were much above MCL of short-time exposure (½ hour), it can be concluded that – in that period of time – the high level of CO concentration represented a dangerous threat for the health of inhabitants in these areas.

The main reason for high values of carbon monoxide concentrations is the intense traffic and the vehicle engine stagnation during a long period of time in both monitored intersections from the city centre of Bucharest. The high carbon monoxide concentration levels were encountered with priority in winter months, a possible explanation being the quantity of carbon monoxide released in atmosphere which may rich maximum levels at starting of cars and usual at low temperature. Another confirmation of road traffic contribution to high level of CO comes from decreasing of carbon monoxide concentrations in week-end days when road traffic is less intense.

Therefore, it can be concluded that the variations of carbon monoxide concentration in Bucharest atmosphere are correlated with intensity of road traffic, the month of year, the week days and the high traffic hours (in the morning and in the evening).

REFERENCES


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