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SILENT DANGERS FROM UNDERGROUND - BUCHAREST SUBWAY AIR QUALITY

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Abstract

Every day, 600 000 people travel by subway. And every day, for a few dozen minutes, these passengers breathe the underground air. Many felt agglomeration, heat, dust. Few people wondered how harmful the particles invade their lungs. In this study we determined concentrations for the particulate matter (PM) and carbon dioxide, as well as the level of noise from the subway. The results are worrying and shows the differences between the maximum admitted and the actual levels that lead, in time, to the illness of the human body

Keywords: *air pollution, health, subway.*

INTRODUCTION

Subway systems offer the city a lifeline that allows the efficient transport of people without adding to road congestion and traffic emissions. The numbers are impressive, with over 600 000 people travelling every day in Bucharest.

One environmental disadvantage of any underground transport system is that it operates in a confined space that may permit dust accumulation. Furthermore, much of the inhalable particulate matter PM in subway platform air is actually produced underground and so is different from that breathed outdoors (Martins et al., 2015).

The sourced of PM in the subway is generated by friction between moving train parts such as wheels and brake pads, giving the particles a peculiarly metalliferous character, with iron being the classic “subway metal” and accompanied by a distinctive cocktail of trace elements (Martins et al., 2015). Ferruginous particles released from wheels for example contain trace amounts of chromium, nickel and cobalt (Adams et al., 2001), levels of which on platforms may rise to 30, 40 times higher than outdoors (Moreno et al., 2017).

In appropriate design and use of ventilation can result in substantial deterioration of subway air quality (Moreno et al., 2018).

Particulate matter are deposited in the lower air layers and manifest a stress over human body, which consist in inflamation of the bronchial tree. These powders have, over time, cumulative, and a carcinogenic effect. In the case of those with respiratory problems, the effects occur in a few minutes, but in healthy people, the first symptoms may occur in a few years or decades of exposure. Low but disturbing loudness that penetrates the man's home from the outside or adjoining rooms due to their permanent action, day and night, is a chronic irritant of the human body.

Noise exposure is a function of 2 main factors: (1) the frequency-weighted exposure level, measured in A-weighted decibels (dB), and (2) the exposure duration. The causal association between chronic exposure to excessive and permanent noise irreversible, noise-induced hearing loss (NIHL) is well known, as are the adverse social, psychological, and occupational effects associated with the condition.

In this study, we noted levels that potentially exceeded the community exposure limits initially recommended by the US Environmental Protection Agency (EPA) in 1974 and confirmed by the World Health Organization (WHO) in 1998. WHO and EPA recommended daily allowable exposure times are 24 hours at 70 dB, 8 hours at 75 dB, 2.7 hours at 80 dB, 0.9 hours at 85 dB, and 0.3

hours at 90 dB. Chronic exposures that exceed these allowable combinations of duration and noise level are expected to produce NIHL in some members of the exposed population (Berglund et al., 1999; EPA, 1974).

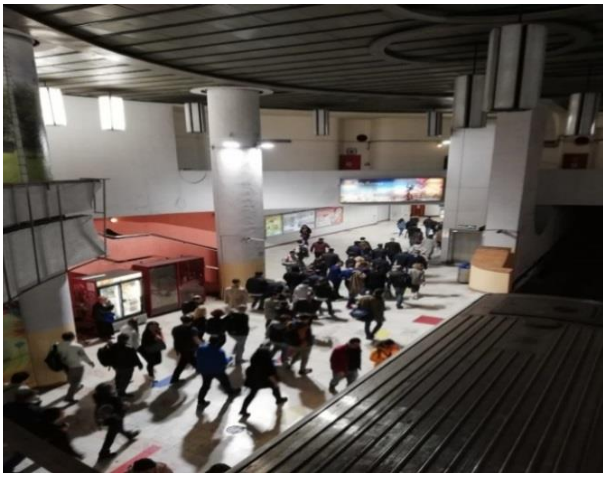

Figure 1. Piata Victoriei subwaystation

High concentration of carbon dioxide at subway cabin is one of the serious environmental concerns because carbon dioxide causes drowsiness, headache, and nerve lessness of passengers.

MATERIALS AND METHODS

The levels of $PM_{2.5}$, PM_{10}, CO_2 and noise were measured during the rush and non-rush hours at the subway in Bucharest. The equipment's were placed on the middle of cabin. The measurement campaign was conducted for a week in March 25 to 31, 2019.
The tools used are broadly presented:
Asound level meter was used for acoustic (sound that travels through air) measurements. It is commonly a hand-held instrument with amicrophone.
The model used to measure sound waves is the CEM DT-85A (Figure 2). The diaphragm of the microphone responds to changes in air pressure caused by sound waves. That is why the instrument is sometimes referred to as a Sound Pressure Level (SPL) Meter. This movement of the diaphragm, i.e. the sound pressure deviation (pascal Pa), is converted into an electrical signal (volts V).
A microphone is distinguishable by the voltage value produced when a known, constant sound pressure is applied. This is known as the microphone sensitivity. The instrument needs to know the sensitivity of the particular microphone being used.
Using this information, the instrument is able to accurately convert the electrical signal back to a sound pressure, and display the resulting sound pressure level (decibels dB). Sound level meters are commonly used innoise pollution studies for the quantification of different kinds of noise, especially for industrial, environmental, mining and aircraft noise.
The current international standard that specifies sound level meter functionality and performances is theIEC61672-1:2013. However, the reading from a sound level meter does not correlate well to human-perceived loudness, which is better measured by a loudness meter. Specific loudness is a compressive nonlinearity that depends on level and also frequency, which can be calculated in a number of different ways.

Figure 2. Sonometer DT 85A

For particulate matter PM concentration, we used the DT-96 particle counter (Figure 3).
The DT-96 particle counter ensures fast and accurate air quality testing by counting the number of suspended particles in the air and by determining the ambient temperature and humidity.
Airborne particles are the most dangerous category of pollutants, as they penetrate directly into the lungs and into the blood stream and cannot be filtered by the human body. The

particles include oxides of various metals, nitrates, sulphates, dusts, salts, etc., some of which are acidic (toxic, carcinogenic, sulfur dioxide, etc.).

It measures separately the number of fine particles with a diameter between 0 and 2.5 µm/microns and the number of particles with a diameter between 2.5 and 10 µm/microns in the air.

To have a comparison term, a human hair has about 100 µm/microns in diameter. It is a measuring instrument used for all maintenance and control of ventilation and air conditioning systems to determine the efficiency of filtration systems and to periodically check particulate concentrations in the air, both in door and production units, as well as outdoors

Figure 3. Particles counter

The model used to measure carbon dioxide in the air is EX CO-200 (Figure 4). This device monitors air quality in schools, office buildings, factories, hotels, hospitals, greenhouses etc.

Figure 4. CO2 measurement device

The obtained results was processed, tabulated and thus represented by graphs that mark the differences between the values.

The stations which were monitored are presented in Table 1.

In the table we used different colors depending on the crowd in the stations, namely:

- red for overcrowded subway stations,
- orange for crowded subway stations,
- green for less crowded stations.

Table 1. The subway station monitored

Subway stations	Hours	Degree of agglomeration
1 Mai Station	08:25	less crowded
1 Mai - Basarab	08:36	crowded
Basarab Station	08:43	crowded
Basarab - P-ta Victoriei	08:47	overcrowded
P-ta Victoriei Station	08:51	overcrowded
P-ta Victoriei Station	09:35	less crowded
P-taVictoriei - P-ta Romana	09:00	crowded
P-ta Romana Station	09:05	less crowded
Eroilor Station	09:56	less crowded
Eroilor Station	09:58	overcrowded
Eroilor - Crangasi	10:14	crowded

Crangasi Station	10:23	less crowded
Eoilor - P-ta Unirii	11:16	overcrowded
P-ta Unirii 1 Station	11:32	overcrowded
P-ta Unirii 2 Station	11:38	less crowded

Figure 5. Piata Victoriei - overcrowded subway stations

During that period of time, we moved to the subway stations in Bucharest and perfomed the measurements for $PM_{2.5}$, PM_{10}, CO_2 and noise levels (Figure 6).

Figure 6. Students performing the measurements

RESULTS AND DISCUTIONS

Concentration of CO_2

The amount of CO_2 in the subway air is growing worrisome at peak times, especially in the passages connecting the subway stations and the wagons (Table 2).

An increased concentration of CO_2 causes, to the exposed people decreased concentration and drowsiness. If the carbon dioxide concentration reaches a value comparable to the concentration of air (about 20%), it may even present a lifetime risk. Between 350 and 450 ppm is the normal level of CO_2 in the atmosphere. In enclosed spaces, the limit of CO_2 concentration for the body to feel no oxygen is 800 - 1000 ppm. In one of the metro wagons at the Piata Victoriei station around 10 o'clock, the device used to analyze the CO_2 concentration showed a huge value of 1571 ppm. At the Eroilor station the value of CO_2 was 1049 ppm.

The specialists recommend that in door the CO_2 concentration to not exceed 1000 ppm.

Particulate matter

LAW no. 104 of 15 June 2011 on ambient air quality sets limits for particulate matter (PM_{10} and $PM_{2.5}$). The monitoring of $PM_{2,5}$ and PM_{10} powder concentrations is required to comply with the requirements of the Directive 2008/50/EC on air quality and clean air for Europe.

The daily limit value or PM_{10}according to the Law 104/2011 is 50µg/m^{3}and for $PM_{2.5}$is maximum 25. In almost all subway stations, where we analyzed the air quality, these values are far exceeded (Table 3). In one station, Eroilor - Crangasi, the values are below the limit imposed by law, 35µg/m^3 for PM_{10} and 21µg/m^3 for $PM_{2.5}$.

Noise level

The noise level is also very high (Table 4). In all areas the recorded noise exceeds 50 decibels. By comparison, at a rock concert, the noise level is, in general, about 110 decibels, and a supersonic plane reaches 130 decibels at takeoff.

The maximum permissible noise limits differ according to the functional utility of the affected environment:

- according to WHO 536 the external noise level is measured at 3 m from the outside wall of your home and must be less than or equal to 50 dB (noise curve 45).
- in the house, the day, the maximum limit is 35 dB (noise curve 30);

At night, the maximum allowable noise level is reduced by 10 dB. Allowed:

max 40 dB out;

max 25 dB in house;

- according to STAS 10009/88, the functional areas have maximum admissible limits of different noise and at their intersection the minimum level is applied. Examples of functional areas and maximum permissible sound level:
- 2 m outside the house - max 50 dB;
- parks, gardens (rest and recreation) - max 45 dB. STAS 10009 also adds that for noise from other sources such as outdoor cinemas, playgrounds, car parks, etc., it is permissible to exceed the value of 50 dB and the noise curve of Cz 45 to 2 m on the facade of a dwelling.

Table 2. CO2 values in the subway station

Subway stations	Hours	Degree of agglomeration	CO_2 min. values	CO_2 max values
			ppm	
Crangasi Station	10:23	less crowded	680	883
P-ta Romana Station	09:05	less crowded	861	883
P-ta Victoriei Station	09:35	less crowded	1571	678
Eroilor Station	09:58	overcrowded	1042	1049

Table 3. PM 2.5 and PM10 concentrations in the subway station

Subway stations	Hours	Degree of agglomeration	PM 2.5	PM10
			μg/m^3	
1 Mai Station	08:25	less crowded	54	92
1 Mai - Basarab	08:36	crowded	48	71
Basarab Station	08:43	crowded	62	107
Basarab - P-ta Victoriei	08:47	overcrowded	49	90
P-ta Victoriei Station	08:51	overcrowded	82	153
P-taVictoriei - P-ta Romana	09:00	crowded	102	231
P-ta Romana Station	09:05	less crowded	133	300
Eroilor Station	09:56	less crowded	32	58
Eroilor - Crangasi	10:14	crowded	21	36
Crangasi Station	10:23	less crowded	64	112
Eoilor - P-ta Unirii	11:16	overcrowded	59	100
P-ta Unirii 1 Station	11:32	overcrowded	36	59
P-ta Unirii 2 Station	11:38	less crowded	31	52

Table 4. Noise level in the subway station

Subway stations	Hours	Degree of agglomeration	Noise level dB	
			Max. values	Min. values
1 Mai Station	08:25	less crowded	85.1	68.2
1 Mai - Basarab	08:36	crowded	88.4	68.2
Basarab Station	08:43	crowded	72.4	66.6
Basarab - P-ta Victoriei	08:47	overcrowded	64.5	61
P-ta Victoriei Station	08:51	overcrowded	75.8	63.8
P-taVictoriei - P-ta Romana	09:00	crowded	74.4	72.8
P-ta Romana Station	09:05	less crowded	77.5	74.6
Eroilor Station	09:56	less crowded	76.2	59.3
Eroilor - Crangasi	10:14	crowded	70.3	62.9
Crangasi Station	10:23	less crowded	74.3	67.4
Eoilor - P-ta Unirii	11:16	overcrowded	73.8	62
P-ta Unirii 1 Station	11:32	overcrowded	71	65.7
P-ta Unirii 2 Station	11:38	less crowded	80.7	61.7

CONCLUSIONS AND RECOMMENDATIONS

The clues resulting from the measurements made, the centralization of the data and the comparison with the maximum admissible values are that the values obtained in the metro stations exceed the maximum values in a fairly high percentage.

There are a number of practical steps that can be taken to improve subway air quality, the first being to create an informed awareness of the problem. An initial air quality audit will assess the current situation on station platforms and inside trains. Everyday city noises are impossible to avoid but there are a few things people can do to help off hearing damage. It can be a good idea to use foam earplugs if you are stuck waiting for the express train.

Other useful solutions could be:

- automatic air dehumidifier for trains (so as not to stagnate there to increase humidity until it becomes suffocating); accidentally this is the effect of any A/C.

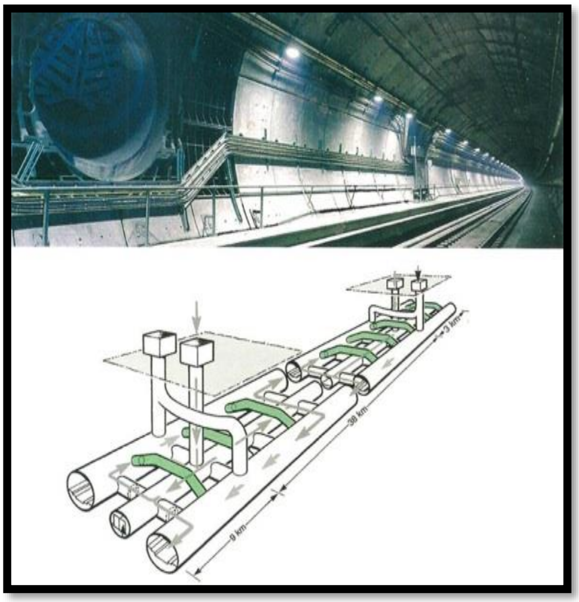

Figure 7. Ventilation system https://www.systemair.com/no/Norge/Produktkatalog/Solutions/Tunnel-and-Metro/Metro-and-Rail/

- better ventilation of the stations to avoid significant temperature differences between the subway and the surface. It is solved by ventilation, in particular.

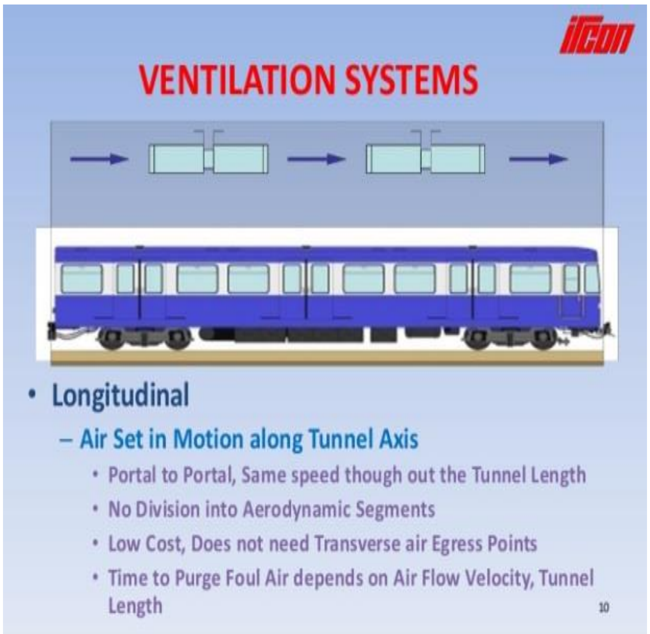

Figure 8. Longitudinal system ventilation https://www.systemair.com/no/Norge/Produktkatalog/Solutions/Tunnel-and-Metro/Metro-and-Rail/

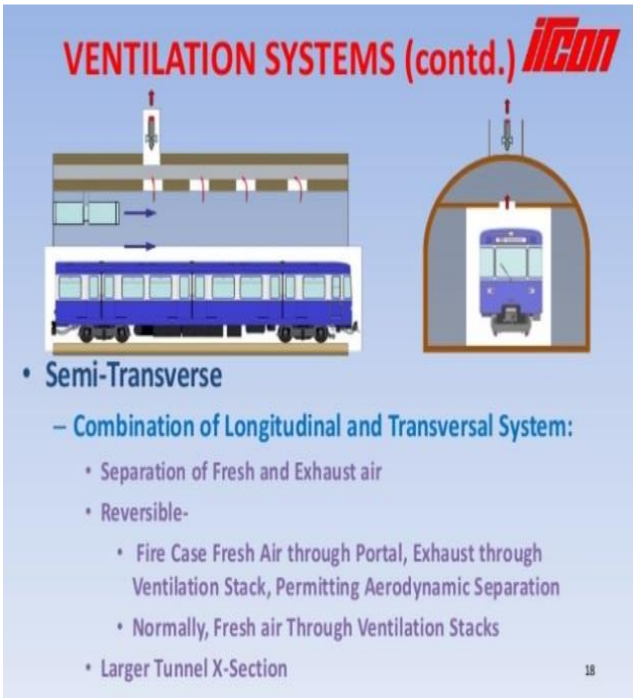

Figure 9. Semi-traverse ventilation system https://www.systemair.com/no/Norge/Produktkatalog/Solutions/Tunnel-and-Metro/Metro-and-Rail/

- evacuating the air from waiting area and introducing fresh air from the tunnel while driving, thus creating a system that allows it to circulate.

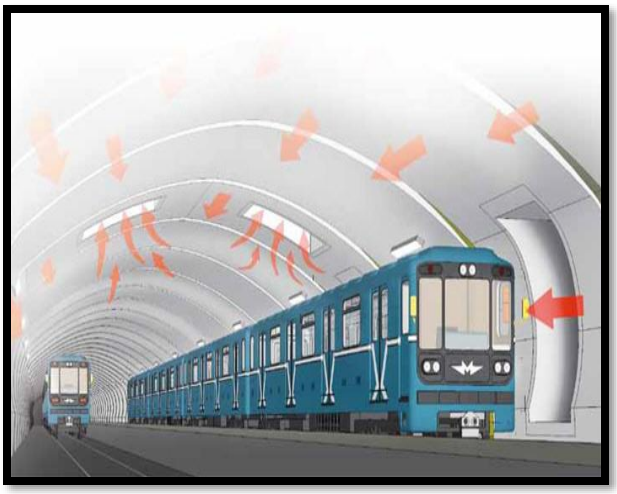

Figure 10. Ventilation of the station https://www.systemair.com/no/Norge/Produktkatalog/Solutions/Tunnel-and-Metro/Metro-and-Rail/

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