Air quality issues in the Bucharest subway system

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Abstract - The subway transport method is come more popular in the last years and in some cities has become the primary public transportation mode. Many people are using the underground transport system because it is an efficient and fast. However, one environmental disadvantage of any underground transport system is that it operates in a confined space that may permit dust accumulation. The passenger typically spend only 30–40 min in metros, the air pollutants emitted from various interior components of metro system as well as air pollutants carried by ventilation supply air are significant sources of harmful air pollutants that could lead to unhealthy human exposure. This article presented the actual situation of the air quality from the subway transport system from Bucharest. An investigation was conducted among for underground subway stations to the examination of practical operation conditions of their cooling units. The overall field testing included information such as air conditioning system formation, equipment types and system.

1 Introduction
The first subway system was proposed for London by Charles Pearson, a city solicitor, as part of a city-improvement plan shortly after the opening of the Thames Tunnel in 1843. On Jan. 10, 1863, the line was opened using steam locomotives that burned coke and later, coal; despite sulfurous fumes, the line was a success from its opening, carrying 9,500,000 passengers in the first year of its existence. Many other cities followed London’s lead.[1] In response to the demand for public transport in Bucharest in 1970, surface runways were developed to handle passenger flows, but they did not offer optimal solutions and conditions of comfort. As a result, it was necessary to introduce the metropolitan transport system, an optimal solution both for the decongestion of surface traffic and for the transport of passengers in safety, comfort and fast speed. Initial work began on September 20, 1975. The tread is located at an average depth of 12 m, ranging from 7.8 m to 19.6 m. The main public spaces and access to the station are sized to support flows of up to 50,000 passengers per hour and sense. (fig. 1)
The development trends of Bucharest determine the implementation of this means of transport: mobility of the population in the city, connection of the city with the metropolitan area, connection of various means of transport, high capacity of transport and distribution in the territory. The objectives of this mode of transport are: accessibility, short journey time of the origin-destination route, safety and comfort of the passengers, reduction of the negative effects on the environment, high transport capacity. To ensure the movement of vertical travelers, lifts, fixed and rolling ladders are used, with a level difference of 5 m to 10.3 m. The Bucharest Metro has an imposing configuration that places it among the most efficient and modern urban transport. His construction continues and this fact confirms once again that Bucharest feels an acute need for the subway.
Figure 1 Bucharest subway map.

2 Air pollution problems

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 40 billion subway journeys being made every year, which is more than five times the current world human population (Teresa Moreno et al., 2018)[2]. Indoor microenvironment was identified as the primary source of human exposure to various air pollutants due to the long time people spent every day (Bin Xu et al., 2018)[3]. Recently, with the rapid development of subway metro system worldwide, human exposure to air pollutants and the related health risk assessment inside metro indoor environment have become of a significant public concern. Metro transit, by avoiding congestion and reducing gasoline consumption, is providing rapid and affordable transportation to urban communities in more than 60 countries.

2.1 Air pollution problem in the city

According to a study conducted in 2010 by Ecopolis (Center for Sustainable Policies) all 8 air quality monitoring stations in the Bucharest-Ifov area have exceeded the daily limit concentrations for PM10. The 3 stations that measure the PM2.5 concentrations registered exceedances for this substance, including for nitrogen dioxide (NO2) and ozone (O3). There was no specific area where the limit values were exceeded, the annual averages for PM10 and PM2.5 were exceeded in all cases. The recorded values were more than 5 times higher for PM10 and 6 times for PM2.5. The effects of pollution in Bucharest are extremely serious. If between 2004-2009 the PM10 and PM2.5 limits were met, over 800
adults and 230 newborns could be saved. If between 2004-2009 the PM10 and PM2.5 limits were met, over 800 adults and 230 newborns could be saved. Among the pollutants found in considerable quantities in the air in Bucharest we can list: Ozone (O3), Carbon Dioxide (CO), Nitrous Oxides (NO, NO2, NO3 ....), Sulfur Dioxide (SO2) and Suspended Particles (PM75, PM50, PM10, PM2.5). [4].

Levels of daily PM10 mass concentrations for the period 2005-2010 in Bucharest-Ilfiov area, including median, the 5th, 25th, 75th, 95th percentiles of their 24-h concentrations. Dotted line represents the annual average. The EU annual limit value of 40 μg m³ (long dashed line) and EU 24-h of 50 μg m³ (long continuous line) are included. Black circles represent first and last 5% of observed PM10. Mihai Bravu- BT, Cercul Militar- CM, Drumul Taberei –DT, Titan-TT, Berceni- BE, Lacul Morii- LM, Magurele-Ma, Balotesti –BT.[4]. 50 μg m³ (long continuous line) are included. Black circles represent first and last 5% of observed PM10.( fig. 2a, 2b, 2c, 2d, 2e, 2f, 2g, 2h.)

**Figure 2a** PM10 measurement

**Figure 2b** PM10 measurement

**Figure 2c** PM10 measurement

**Figure 2d** PM10 measurement
According to the latest data, 25,000 annual deaths are recorded in Romania due to pollution.

2.2. Air pollution problem in the subway system

Average journey times last around one hour so that many underground rail commuters are routinely exposed to transient doses of inhalable particulate matter (PM) levels higher than the 50 μg/m³ mean PM10 (PM b10 μm in size) limit legally imposed for outdoor European city air. According to official data, the subways in Bucharest transport around 600,000 people per day. In figures 3 and 4 the number of passengers per year and on the bus are displayed. (fig 3,4). In fact, PM levels are commonly much higher than those above ground, as demonstrated by an array of recently published studies with of the main sources of pollution in the world's metro systems; (fig.5) in subway systems from cities as varied as Los Angeles, Barcelona, Milan, Paris, Prague, Rome, Stockholm, Seoul, Shanghai and Taipei. [5](Adams, H.S., Nieuwenhuijsen, M.J., Colvile, R.N., Mcmullen, M.A., Khandelwal, P., 2001. Fine particle (PM2.5) personal exposure levels in transport microenvironments, London, UK. Sci. Total Environ. 279, 29–44.).
Admissible limit values: 0.035 - 0.045% vol. - the typical concentration of CO2 in the atmosphere, with human-induced growth tendencies. 0.06 - 0.08% vol. Admissible duration of the concentration, which has no side effects. 0.1% vol. Limit of the long-term concentration in the rooms. 0.5% vol - admitted level at an 8-hour exposure. 0.6 - 3% vol. Admitted level of concentration at short exposure. 3 - 8% vol - range of CO2 concentration that causes changes in biophysical parameters. > 10% vol - level of CO2 with symptoms of intoxication. > 20% vol - the level of CO2. [6]
3 Measurements Bucharest Subway System

In 2018 due to the "scandals" in the press regarding the quality of the environment, respectively the air quality in the station system and tunnels of the Bucharest metro; the following measurements were made public from 10.12.2018. The bioclimatic comfort parameters have been determined in the subway stations: Piata Victoriei 1, Universitate, Piata Romana, Unirii 2 and Piata Tineretului on 29.10.2018, the following values being recorded: Oxygen - the determined values are between: 19.8% vol ( platform Piata Victoriei 1) and 20.9% vol ( vestibule Piata Unirii 2 and Tineretului). Admissible value between: 18-21% vol - is derived from the chemical composition of the air: •inspired nitrogen - 78.08%, expired - 78.26% •oxygen - inspired - 20.94%, expired 16-17%, •carbon dioxide - inspired 0.03-0.04%, expired 3-4%. Oxygen drops in air up to 18% do not cause disturbances. At concentrations between 15 to 18%, mild symptoms occur, but the body is able to compensate for it: they increase heart rate and arterial pressure [12,13]. Carbon dioxide - the determined values are between:0.05% vol (vestibule Piata Romana) and 0.12% vol. ( platform Tineretului). Outside: 0.04% vol (Piata Romana ) and 0.06% vol (Piata Victoriei 1 si Tineretului). [7],[8].

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Suspended powders - the determined values are between: Outside - 0.008 mg / m3 (PM10) – Piata Romana and 0.029 mg / m3 (PM 10) – Universitate 0.142 mg / m3 (PM2.5) - Piata Romana and 0.596 mg / mc (PM 2.5) - Universitate Platform - 0.021 mg / m 3 (PM 10) - Piata Romana and 0.213 mg / m3 (PM 10) – Piata Unirii 2. 0.397 mg / m 3 (PM 2,5) - Piata Romana and 4.8 mg / m 3 (PM 2,5) - Piata Unirii 2 Vestibule X - 0.011 mg / m 3 (PM 10) – Piata Romana and 0.090 mg / m 3 (PM 10) – Piata Victoriei 0.198 mg / m 3 (PM 2,5) - Piata Romana and 2.188 mg / m (PM2.5) – Piata Victoriei. Vestibule Y - 0.019 mg / mc (PM 10) - Universitate and 0.085 mg / mc (PM 10) - Piata Victoriei 1. 0.326 mg / m3 (PM2.5) - Universitate and 1.57 mg / mc (PM2.5) - Piata Victoriei.(fig. 6a, 6b, 6c, 6d, 6e.)[11],[12].
4 Ventilation systems in the Bucharest subway

The system of general and technological ventilation installations includes the following elements:

a) General ventilation system of adjacent stations and tunnels (fig 7,8)
b) Ventilation systems of the electrical traction substation
c) General ventilation system reactivation systems
d) Ventilation systems of sanitary systems
e) Ventilation systems of other technical spaces

Types of fans general ventilation systems:
VAM 1800 - axial fans; VM 18 - centrifugal fans; WOODS - axial fans.
The intake / exhaust air flow varies between 100,000-220000 m³/h. The intercooler's ventilation system includes the following elements: air outlet with the outside (fig. 7), opposite damper chassis actuated by servomotors, noise attenuators (fig. 7, 8), filters, CUS,(fig. 11, 12) fans and air intake in the tunnel.(CUS = humidification chamber)(fig 9, 10). The most important is the it station ventilation and interstation technology, which takes the outside air (out of town) through the external ventilation sockets and introduces into the subway system. This assembly assures the introduction of the fresh air through the station / interstation and the evacuation of the vicious air through the station/interstation.

The general ventilation system for metro stations and tunnels is a set of ventilation modules. Each general ventilation module includes a subway station and adjacent tunnels, as well as the necessary installations: the general ventilation installation of the station and the general ventilation installation of the subway interstation. The air heats up by evacuating the heat from the system and the harmful effects
are evacuated by the general ventilation system of the station. During the summer the type of humid air evolutions: - adiabatic, where the air is cooled in humidification chambers with recycled water Winter operation - fresh air is introduced through the main ventilation system of the interstation. The air heated by the heat released in the tunnel by the circulating TEM, is led inside the metro station, takes over and is evacuated outside by the central ventilation station of the station. During the intermediate seasons (spring, autumn), the general ventilation installation of all underground tunnels will operate normally as prescribed by the specialized laboratory. In the case of outside temperatures below -5 °C, the general ventilation (of the station) is cut off, the air being expelled outwards due to the piston effect.[13]

4.1 Ventilation systems in trains
Metrorex Railroad Park is made up of 3 types of trains: The BM3 Metro Unit in Bucharest (fig11,12,20) manufactured by CAF for S.C. METROREX, S.A., is a train composed of 6 different wagons that have been designed to provide services on the underground lines M1, M2, M3, M4 and M5 of the Bucharest subway network.(fig. 13, 14, 15, 16).[14]
The units are equipped with a ventilation unit in the passenger compartment of each wagon and with a heating, ventilation and air conditioning system (HVAC) in each cab. Salon Ventilation System: Each wagon of the unit is equipped with a passenger compartment ventilation unit. Each ventilation unit is installed at one end of the wagon and consists of two centrifugal fans with a capacity of 6,000 m³ / h for each wagon. The ventilation equipment takes over the air from the upper entrance of the unit and, after passing it through the filter, propels it into the salon through the air distribution duct along the entire wagon. A grid is provided on one end of the wagon to allow extraction of air in case of overpressure (fig 17).

Ventilation of the salon - Air circulation. Ventilation equipment begins to operate as soon as it is powered by three-phase (400 Vac). In this situation, the equipment starts to operate automatically in...
accordance with a predetermined adjustment curve, depending on the outside temperature and the passenger load on the train. The driver can connect / disconnect the equipment via a button in the cabin console. If the machine is turned on (manual or automatic), when this button is pressed, the machine stops running. By pressing it again, the TCMS sends the start-up command to the ventilation unit, always in automatic mode. The driver can connect / disconnect the air flow through a switch in the cabin console. Once this switch is in use, the machine switches from manual mode to automatic mode. To return to automatic mode, press the ventilation control button twice: Once to turn off the unit and the second time to start operating automatically.

Bombardier ventilation system:
The HVAC system consists of the forced ventilation units in the area for passengers (fig. 18) and HVAC units in driving cabs. The forced ventilation installation. At the end B of the roof of each wagon there is a ventilation unit forced. The forced ventilation unit is provided with a plug cap air supply and, in the interior, an air filter. The air is distributed through air ducts and through feed holes with air, along the ceiling lights. Air Conditioning (HVAC). The cabin air conditioning unit is mounted on the roof of the Wagons R. Air is supplied inside the cab via the pipes, the air inlets and the discharge nozzles. Mechanic can regulate the flow of air through the nozzles. The air intake outlets are located on the side of the unit and are provided with a grid. Technical data Weight125kg.Load rating 2.1kVA Rated power 400 V Air volume max 4000 m³ / h. [15]

![Figure 18 Airway trap on the top of the wagon](image)

IVA subway; they have a natural ventilation. G2 filters are present in the air outlets. I will not present much about this type of train because in 2022, its running time will end. Air filter: PSB 275s Viledon2000x395 mm, used for ventilation of both types of trains.

This type of train runs on the 4th subway line (Northern Railway Station-Straulesi Station). [16].

5 Conclusions
Contemporary man must be, and in fact it is in a continuous, alert, Metrorex makes every effort to providethe public with a modern public transport. The society develops continuously by adapting to demands market. The Bucharest metro provides a transport today comfortably and economically, maintains its market share and transported more than 700,000 passengers daily, almost in all areas of the city. In the hierarchy of European countries the subway Romanian is placed in the first half of the standings, with a certain upward trend in the ranking. We see growth the number of people who opt for subway.

Because the ventilation system of the substations and subway tunnels is a reversible "open system" that carries significant airflows (up to 300,000 m³ / h) across the entire length of the subway buses, it is not possible to filter out the air introduced from the outside considering and the role of this ventilation system in case of emergency.
Due to the large airflows flowing from the general ventilation system, to which are added the flows created by the piston effect and considering that by the access of the stations the overpressure / depression air circulates freely, technically it is almost impossible to create cooling systems and air filtration.

However, considering that each ventilation system in the subway stations and substations has its particularities and most of it is built earlier in the 1990s, it must be taken into account that Bucharest was and is in continuous development and rehabilitation.

For example, outdoor air intakes due to the fact that parking or other constructions have been set up have only reached the same level of construction as the carriageway and can now introduce much more vicious air than in previous years.

Another example of improving air quality is related to trains. or the number of passengers entering the continuous growth, it was chosen as a quick solution and namely: mounting of swing windows at the top of the saw.

By evaluating the two examples, we can develop solutions for improving air quality as follows: a) Introduction of outside air from a level difference with the carriage between 1m - 3mH, b) Elaboration of solutions for the efficient ventilation, c) systems present in the subway electric trains, d) Conducting experimental studies to develop an air filtration system without affecting current flows.

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