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Reducing the concentration of fine dust particles in underground rail transport

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Abstract: *The article describes the basic requirements in underground public transport and the types of pollutants. Existing approaches to improving the subway environment are presented. Ventilation and air filtration are discussed.*

Keywords: *tunnels, metro, metro stations, fine dust particles (FDP10, FDP2.5), doors, trains, ventilation, filters*

1. Introduction

High concentrations of FDP cause many diseases and respiratory problems worldwide. The metro is used by millions of people around the world daily /only in Sofia over 450,000 passengers use the metro per day with a tendency to increase their number with increasing lines/. Ensuring the health and safety of passengers and staff is essential.

Also, the danger of terrorist attacks has increased in recent years. Some of the most vulnerable places are in urban transport infrastructure, especially metro stations and tunnels. Here there is a coincidence of crowding of large numbers of passengers, relatively little place for reaction and exit, as well as large and expensive engineering facilities.

Objective of the survey - Innovative approaches to the management of protection systems in underground public transport in order to improve air quality and passenger safety.

2. Metro and general requirements

The metro (abbreviated to the Greek metropolis: city-mother, also known as the underground railway) is a fast public transport.
The subway is designed with stations at important transport hubs, office buildings, shopping centers, landmarks, neighborhoods and other sites..

Metro lines and their individual sections may be underground (tunnels), terrestrial and overground (bridges and estacades). The total length of the lines in different cities may range from 2-3 kilometers. to over 1300 km. (subway in New York).

The benefits include:

- Fast and efficient (high capacity) - Typical capacity is 1200 passengers per train or 36 000 passengers / hour. They can also reach up to 80,000 passengers per hour.
- Reliable transport / Accurate timetable /
- Comfortable transport
- Others

Due to the extensive use of underground transport, the ventilation system is essential for the comfort, health and safety of passengers and staff. It must be designed to provide a comfortable environment for passengers and handling personnel at their normal operation (temperature and air quality). The system should be able to deliver fresh air during the "peak hour" as well as control the smoke movement and direction and ensure safe evacuation during an accident.

More important requirements:

 Removal of generated heat

- Subway trains can be regarded as moving sources of heat. Heat generation is mainly generated by the braking system, train air conditioning systems, etc., as well as by passengers.
- The most effective way to remove heat is immediately after it is generated to prevent it from spreading into the environment of the station and tunnels.

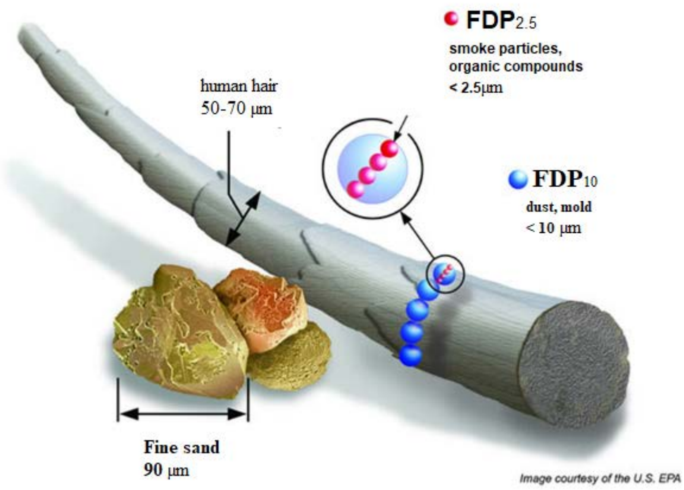

Fig. 1. Particle size attributed to human hair

 Ensure good air quality
- A number of air quality studies have been conducted in the subway and, as a result [3], because of train movements, concentrations of fine dust particles (FDP2.5 and FDP10), and in particles concentrations of iron, magnesium and chromium exceeded the values of air overground /over 100 times on New York subway/ [1].
- Impact on human health [16, 17, 18]

The dust comes into the body primarily through the respiratory system, where larger particles are retained in the upper respiratory tract, and the finer particles (below 10 microns - FDP10) reach the lower respiratory tract, causing damage to the tissues in the lung (Fig. 1). Children, adults and people with chronic lung disease, influenza or asthma are particularly sensitive to high FDP10 values.

The harmful effect of dust pollution is more pronounced with the simultaneous presence of sulfur dioxide in the atmospheric air. Their synergistic effect on respiratory organs and open mucous membranes was established. It is irritating and depends on the duration of exposure. The short-term exposure to 500 mg/m3 of dust and sulfur dioxide increases the overall mortality rate in the population, and at half-lower concentrations there is an increase in morbidity and impairment of pulmonary function. Prolonged exposure to sulfur dioxide and dust is manifested by an increase in non-specific pulmonary diseases, mainly respiratory infections of the upper respiratory tract and bronchitis at significantly lower concentrations (30-150 mg/m3), which is particularly pronounced in children. The most vulnerable to the combined effects of dust and sulfur dioxide are chronic patients with bronchial asthma and cardiovascular disease. The harmful effects of exposure to high concentrations of metal dust particles have been documented in a number of toxicological and epidemiological studies. In samples taken from a Stockholm metro, {2} there is an 8 times greater likelihood of DNA damage and four times higher probability to cause oxidative stress (diabetes, cancer, Alzheimer's disease, arthritis etc) in cultivated lung cells. Samples taken from three London metro stations have a higher inflammatory potential and are more likely to cause DNA damage in cultivated human epithelial cells than in overground FDP.

Particle characterization in the subway - The particle distribution and type was made in a study [9] conducted in South Korea with samples of dust particles taken from different locations in several stations (Fig. 2).

In case of a fire in a tunnel or a metro station, the greatest danger is not the flames, but the inhalation of the poisonous gases generated by the burning toxic products (Over 70% of the victims are in case of poisoning). Most toxic and most commonly released in case of fire are oxides of hydrocarbon CO /binds to blood hemoglobin 200-300 times faster than oxygen - there is oxygen starvation of the organis / and CO2 - cause of 50-80% of the dead. CO2 replaces oxygen in the blood, speeds up breathing, so larger amounts of other gases are absorbed in more dangerous concentrations, at 10% - man loses consciousness. In the event of a fire or a terrorist attack, harmful gases must be removed as quickly as possible from the metro area while providing fresh air for passengers, personnel and firefighters.

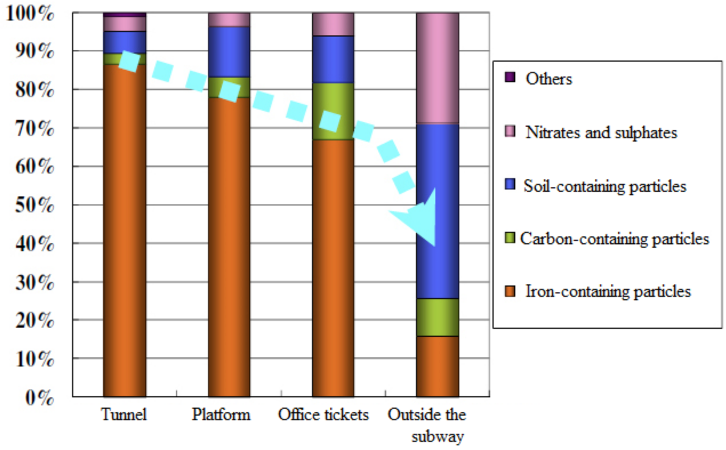

Fig. 2. Particle distribution by classes

Terrorist Attack [20] - the main ways of attacking (sarin, anthrax) are by putting them on the station, on the train or in the tunnel - possibly through the ventilation shaft. The propagation occurs when trains run through the stations and tunnels. Installing detectors and CCTV and analytical software could reduce response time and take immediate action.

3. Technological level and developments at that time

There are several approaches to improving the subway environment:

• Installation of automatic sliding doors on the stations [14], fig. 3:
Advantages: Reduces noise, dust, wind, prevents accidental drops from the platform, improves climate control of stations, reduces jamming on rails and tunnels /against fire/.

Fig. 3. Sliding doors on a station

Disadvantages - a high cost of fitting, maintaining and adjusting the doors to those of the trains, reduces the effect of natural ventilation, which increases the cost of ventilating the subways. There are incidents incl. deaths in which a passenger falls between the closed door of the train and the sliding door of the platform.

• Air curtain. In the recent years, studies, tests and simulations using air curtains have been conducted, [10]. As a result, dust particles pollution is reduced and tunnel ventilation is improved. A disadvantage can be the power consumption and the generated noise that cannot be distributed effectively in the environment. Research has found that an air curtain effect will have when the airflow rate is at least 25 m/s, and studies with 60 m/s and 80 m/s have been made, /fig.4/.

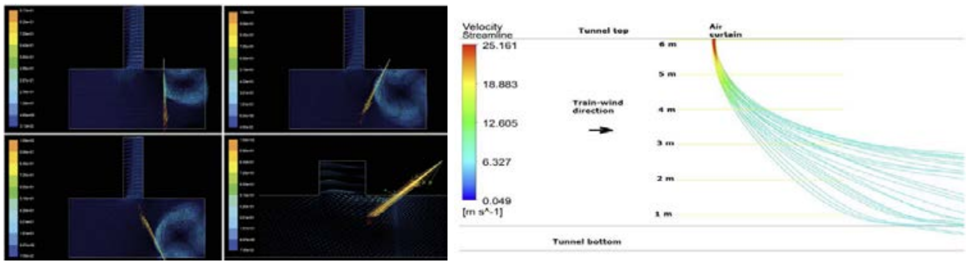

Fig. 4. Simulation of air curtain

• Use of a vacuum train to clean tunnels from dust and debris - Fig. 5, [11]

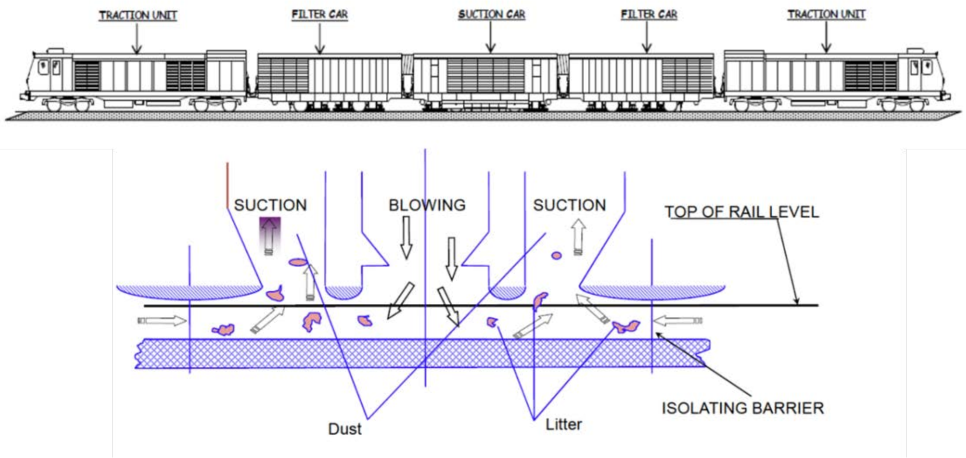

Fig. 5. Vacuum train to clean tunnels from dust and debris

4. Ventilation in the subway and tunnels

Natural ventilation in the subway is mainly the result of the movement of trains through the tunnels. Airflows are similar to those caused by the piston movement in a cylinder and for this reason it is called ventilation of a "piston effect".

"The effect of the piston" is a phenomenon and is the cause of the air movement from the tunnels to the metro stations as well as the change in pressure. From a ventilation point of view, air movement is functional and helps to exchange air, tunnel cooling, etc., but when the "plunger effect" is more, it is the cause of high air velocities on the platform and corridors. To reduce the high air velocity, shafts are designed to deviate the air from the tunnels to the atmosphere and reduce wind gusts in the stations. Gusts of wind enter the stations as a stream that expands in the cross section of the station and reaches about 15-45 m/s inside it [4, 5]. Normally, the wind speed should not exceed 5 m/s when entering the station [12].

Stairs, escalators and entrance corridors also act as ventilation shafts, and the "piston effect" can cause excessive air velocities in these areas.

The air flows in the subway are generated by two main sources: the "piston effect" of train movements through tunnels and, in some cases, mechanical ventilators. A natural source of air is also the staircase and other openings. Factors that affect airflow are geometric parameters such as: location, shape, length, cross-section, perimeter, roughness of walls in tunnels, stations and ventilation shafts, as well as dynamic parameters: train speed, acceleration, stroke, as well as the performance of the fans. The air temperature, its speed and pressure depend on the design of the tunnel ventilation system. "The effect of the piston" is the cause of the air flow through tunnels from the tunnels to the outside atmosphere, and in the opposite direction - a stream of fresh air when the train passes through the shafts.

The hot and warm air generated by the train braking system and the air conditioning system is mixed with that from the tunnel behind the train, which is subsequently transferred to the station due to the remaining momentum or pulled out as a result of the train's departure [6].

The "piston effect" generated by train movements is in most cases sufficient to maintain a good level of ventilation.

5. Air filtration

Air filters are generally classified based on their collection efficiency, pressure drop (airflow resistance) and particle retention capacity. Two test methods are currently in use: European Standard EN 779 and US Standards ASHRAE 52.1 and 52.2 for Classification of Ventilation Air Filters. The classification of these filters is based on the efficiency gained from conducting experiments.

The American standard ASHRAE has confirmed the so-called MERV - minimum efficiency reporting value, values by which manufacturers evaluate the performance of their filters. To measure this efficiency, 12 sizes are entered. The smallest particle size is 300 nanometers.

Rough and fine dust filters are most commonly used for air purification. Based on their performance, the EN779 classifies the various fine-grained F5-F9 filters, where F5 is less efficient and F9 is the most efficient of all. Class filters G1-G4 are coarse filters.

The MERV / HEPA / ULPA filters are used for air purification in laboratories, industrial premises, clean rooms, hospitals, electrical appliances, and more. Fig. 6.

Depending on the selected filter, it is possible to filter: bacteria, 90-99% fine particle size 2.5-10 microns, mold spores, etc.

6. Conclusion

Air cleanliness and subway safety are of great importance due to the fact that this mode of transport is used by millions of people. The presented in the paper pollutants and methods for their cleaning improve the environment in underground urban transport and help to increase security.

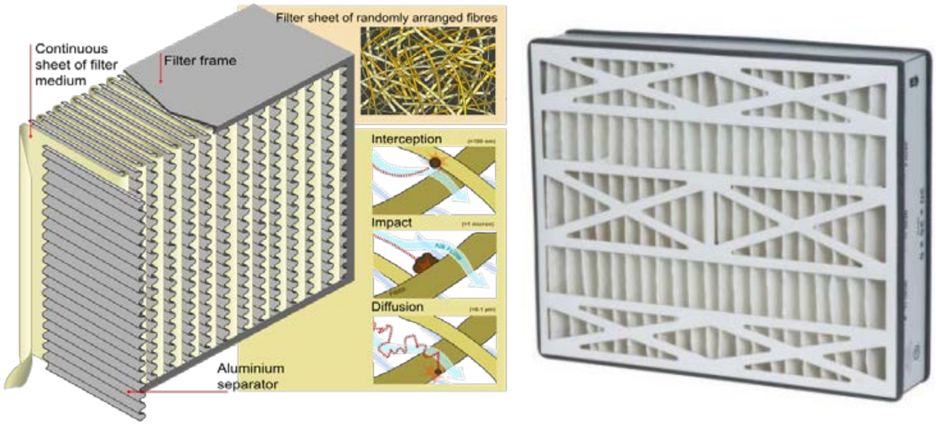

Fig. 6. Filters MERV/HEPA/ULPA

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Уменьшение концентрации мелких частиц пыли в подземном железнодорожном транспорте

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Р е з ю м е:

В статье описаны основные требования к подземному общественному транспорту и видам загрязняющих веществ. Представлены существующие подходы к улучшению среды метро. Обсуждаются вентиляция и фильтрация воздуха.

Ключевые слова: туннели, метро, станции метро, мелкие частицы пыли (FDP10, FDP2.5), двери, поезда, вентиляция, фильтры