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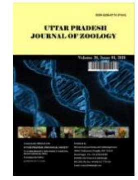

THE IMPACT POLLUTION WITH MATERIAL PARTICLES ON VEGETABLE COMPONENTS

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author COR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MR and DS managed the analyses of the study. Author MR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In this paper is analyzed the impact on pollution with material particles PM 10, PM 2.5 on vegetation. The effects of particles of vegetation are: reduced light required for photosynthesis, increased leaf temperature due to changes in surface optical properties, impaired respiration, impaired stomatal function, reduced leaf area in the immediate vicinity of pollutants, reduced concentration of photosynthetic pigments, chlorophyll and directly plant productivity. Pollution caused by road transport on vegetation results from changes in soil chemistry, composition or foliar chemistry. The impact on the vegetation occurs 1 km from the road due to the rapid dispersion of air pollutants of vehicles. The leaves of plants capture pollutants, their assimilative organs being directly affected by air pollution. The material particles PM 10 ((is a mixture of very small particles with a diameter of 10 micrometers or less) and PM 2.5 (is a mixture of very small particles with a diameter of 2.5 micrometers or less), temperature, relative humidity and wind speed were monitored in interval November 01.11.-08.11.2020 and 01.01-20.11.2020 with the weather station from the Polytechnic University of Bucharest, Faculty of Biotechnical Systems Engineering, Romania. The presence of vegetation led to the decrease of material particles, by the absorption of material particles by the leaves of plants. Meteorological parameters influence the level of particulate pollution, in conditions of high temperature, clear sky and low wind, the concentrations of PM 10 and PM 2.5 reach higher levels.
The structural aspect of the PM10 and PM 2.5 material particles were highlighted by optical and electron microscopy

Keywords: PM10; PM 2.5; pollution; vegetation.

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1. INTRODUCTION

The objectives of the study are to highlight the pollution with PM 10 and PM 2.5 material particles on the vegetation.

Economic growth, urbanization and concentration of population in cities, chemicalization of agriculture have consequences on the environment and human health due to increased pollution [1].

The effects of dust on vegetation are: decreased light available for photosynthesis, increased leaf temperature due to altered optical properties of the surface, impaired respiration, impaired stomatal function [2,3,4,5,6]. When absorbed by the leaves, the material particles reduce the concentration of photosynthetic pigments, the content of chlorophyll in the leaves and carotenoids, which directly affect plant productivity [1,7].

The presence of vegetation leads to a decrease of material particles in the air by 27.7%, by the absorption of material particles by plant leaves [8].

Particulate matter PM 2.5 is a mixture of very small particles with a diameter of 2.5 micrometers or less, usually described as fine particles coming mainly from anthropogenic and natural sources [9]. Natural sources have: volcanic eruptions, rock erosion, sandstorms, forest fires or other vegetation [10,11]. Anthropogenic sources represent 10% of the total and result from various human activities: burning fossil fuels, emissions of internal combustion engines, from wear of car parts and tires, wind dust, industrial activity, public heating systems, road traffic, cement and asbestos factories, steel rolling mills, metal foundries, thermoelectric power plants, which run on solid fuels, cotton husking plants, combustion sources such as engine exhausts, grain handling elevators, dust-generating construction sites, factories, printers, car and subway brakes, aircraft tires when in contact with the runway, wood and coal burning grills and biomass burning [12].

PM10 are suspended particles with a diameter of 10 micrometers or less are mainly due to road dust and mechanical processes, tires and brake emissions, particles derived largely from incomplete burning of fossil fuels and burning of biomass [13].

It was observed in the case of spruce forests exposed to traffic emissions, the increase in the number of trees that show symptoms of defoliation at 200 m from a road with 10,000-15,000 vehicles / day. The influence of the highway has spread to about 150 m [14]. Tall oaks and cedars planted 25 m from a road halved the concentrations of PM10 and PM2.5, the tall grass in the pasture reduced the particle concentration by 35%. In Chicago (USA) urban trees, which occupy 11% of the city's area, have removed about 234 tons of PM10 per year [15]. In studies realized in cities in the UK, planting trees in a quarter of the available urban area has reduced the concentration of PM10 by 2 to 10% [16]. A 100 m barrier of sparse vegetation reduced PM10 concentrations by less than 10% and 17-25 µm particles by 25%.

2. MATERIALS AND METHODS

The material particles PM 10 and PM 2.5, air temperature, relative humidity and wind speed were monitored between November 1-8, 2020, with the weather station from the Polytechnic University of Bucharest, Faculty of Biotechnical Systems Engineering. The microbial flora in the air was determined by the sedimentation method. During the analyzed period, air samples were taken in front of the faculty in Petri dishes and were counted bacterial colonies. The structural appearance of PM2.5 and PM10 material particles was highlighted by optical and electron microscopy SEM

3. RESULTS AND DISCUSSION

The diameter of PM material particles was declared standard at 10 µm in 1989, and in 1997 up to 2.5 µm according to SR EN 14907/2006, [17]. PM2.5 is a solid pollutant with a diameter of less than 2.5 micrometers, and PM10 has a diameter of less than 10 micrometers.

Romanian legislation does not indicate a maximum accepted level for the content of PM2.5 in ambient air, according to the National Ambient Air Quality Standards (NAAQS), the limit imposed for PM2.5 is 35 $\mu g/m^3$ according to SR EN 12341/2002, [18]. Concentrations of suspended particles with a diameter of less than 10 microns - PM10 in the ambient air are evaluated using the daily limit value, determined gravimetrically, ($50\ \mu g / m^3$), which must not exceed 35 times / year and the annual limit value, determined gravimetric ($40\ \mu g / m^3$).

The chemical compositions of PM2.5 and PM10 are presented in the Table 1, [19].

The chemical composition of PM2.5 and PM10 material particles could be attributed to pollution due to diesel vehicles in this study.

Table 1. The chemical compositions of PM2.5 and PM10, [19]

Chemical elements [%]	PM2.5	PM10
Chloride (Cl^-)	0.42	1.4
Nitrate (NO_3^-)	2.6	4.5
Sulfate (SO_4^{2-})	12.7	14.1
Soluble sodium (Na^+)	1.5	2.5
Ammonium (NH_4^+)	2.8	3.0
Soluble potassium (K^+)	0.59	0.68
Sodium (Na)	0.72	1.5
Magnesium (Mg)	0.20	0.41
Aluminum (Al)	0.30	0.96
Silicon (Si)	0.54	1.8
Phosphorus (P)	0.20	0.20
Sulfur (S)	4.9	5.2
Chlorine (Cl)	0.31	1.3
Potassium (K)	0.71	0.97
Calcium (Ca)	0.22	0.97
Titanium (Ti)	0.023	0.075
Vanadium (V)	0.018	0.019
Manganese (Mn)	0.031	0.050
Iron (Fe)	0.57	1.8
Nickel (Ni)	0.0058	0.0066
Copper (Cu)	0.024	0.057
Zinc (Zn)	0.30	0.35
Arsenic (As)	0.016	0.016
Bromine (Br)	0.014	0.019
Rubidium (Rb)	0.0052	0.007
Strontium (Sr)	0.0048	0.010
Zerconium (Zr)	0.0077	0.012
Tin (Sn)	0.029	0.034
Antimony (Sb)	0.041	0.050
Barium (Ba)	0.048	0.090
Lead (Pb)	0.061	0.069

The deposition velocity of the airborne particles and gas molecules (v_d) is described as the the reciprocal of resistance to deposition, $R_{tot,}$ is calculated according to the relation (1):

$$v_d = \frac{1}{R_{tot}} = \frac{1}{R_a} + \frac{1}{R_b} + \frac{1}{R_c} \quad \text{(Eq. 1)}$$

R_{tot} (equation (1)) is a sum of resistances: R_a the aerodynamic resistance, R_b the limit resistance and R_c the surface resistance [7].

The aerodynamic resistance is considered low compared to the other types and is zero, unless the study focuses on particles with a high settling speed, ie with a particle diameter greater than 10 μm. The deposition rate is higher than the settling speed. Aerodynamic drag depends on dispersion.

For aerodynamic drag, R_a, meteorology is important, R_a and boundary layer strength, R_b, depend on the speed of friction or shear.

The deposition rate for 0.2-0.5 μm particles depends on the atmospheric stability of the described boundary layer, the Monin-Obukov length, L and the particle diameter, D_p (equation (2)), of the empirical constant A, which is 0.63 when crossing pine forests, 1.35 over other forests and 0.2 over grass.

$$v_d = A \cdot u \cdot D_p \cdot \left(1 + \left(-\frac{300}{L}\right)^{2/3}\right) \quad \text{(Eq. 2), [7]}$$

The minimum deposition rate reported in the literature is 0.1-0.3 μm [7]. The deposition rate for supermicrometric particles increases with size due to the increasing impact rate and for sub-micrometric particles decreases with size [20].

Hygroscopic (marine) particles can increase their deposition rate by 5 to 6 times, changing the relative humidity from 40% to 99% and depositing 16 to 25 times faster by 99.9% relative humidity.

Meteorological parameters influence the level of particulate pollution, in conditions of high temperature, clear sky and lack of wind, dust concentrations reach higher levels of PM2.5 and PM 10.

In Fig. 1 we graphically represented the values of PM 2.5 and PM 10 material particle concentrations, wind speed, relative humidity and air temperature monitored with the AWS / EV weather station from the Faculty of Biotechnical Systems Engineering at the Polytechnic University of Bucharest , Romania, between January 1 - December 17, 2020 and November 1 - November 8, 2020. It is observed that there are increases in concentrations of PM 2.5 and PM 10 in the days when the wind speed was reduced, when the relative humidity was increased and when the air temperature was slightly raised.

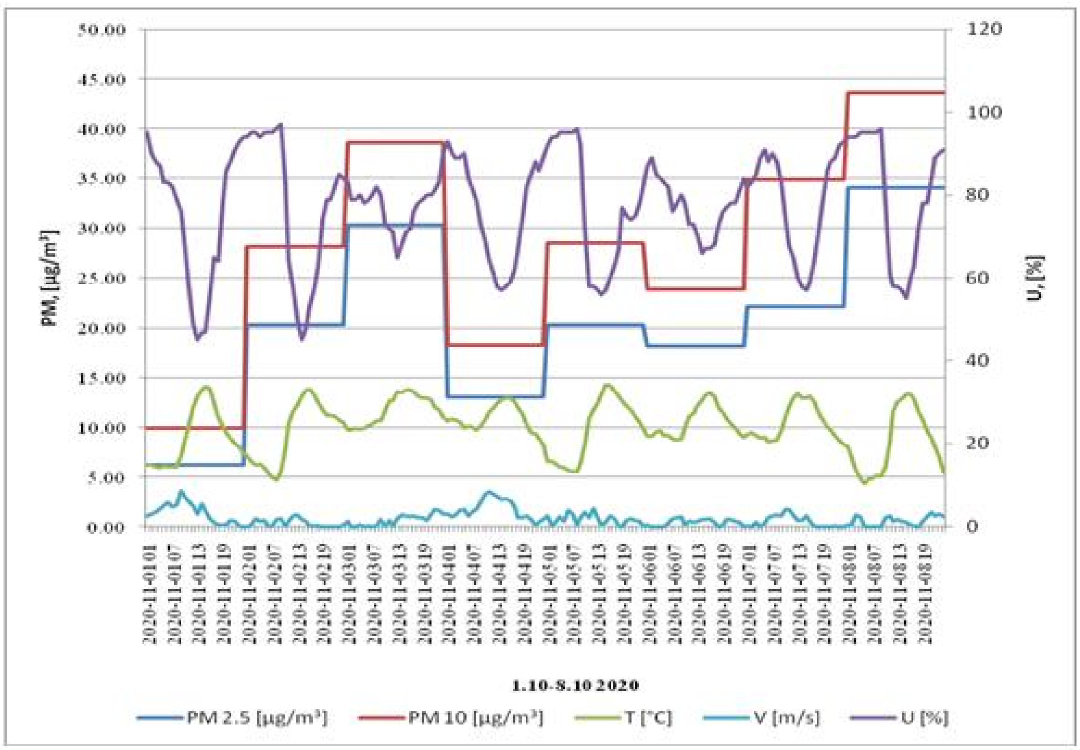
There were no exceedances of PM 10 and PM 2.5 in the analyzed period, being a protected area, there is a lot of vegetation (trees, flowers), the number of cars is very small. Fig. 1b shows the variation of the material particle concentration between 1 January and 17 December 2020 and the values of air temperature, wind speed and relative air humidity.

The area where the measurements were made, in front of the Faculty of Biotechnical Systems Engineering at the Polytechnic University of Bucharest, Romania, being a lot of vegetation, being low pollution, the values PM 2.5 and PM 10 did not exceed the values provided in the standard. Road vehicles are an important source of air pollution.

Fig. 2 shows the source of pollution emissions with PM 10 and PM 2.5, road traffic emissions have the largest contribution (29%) of the total mass of PM 2.5 [19]

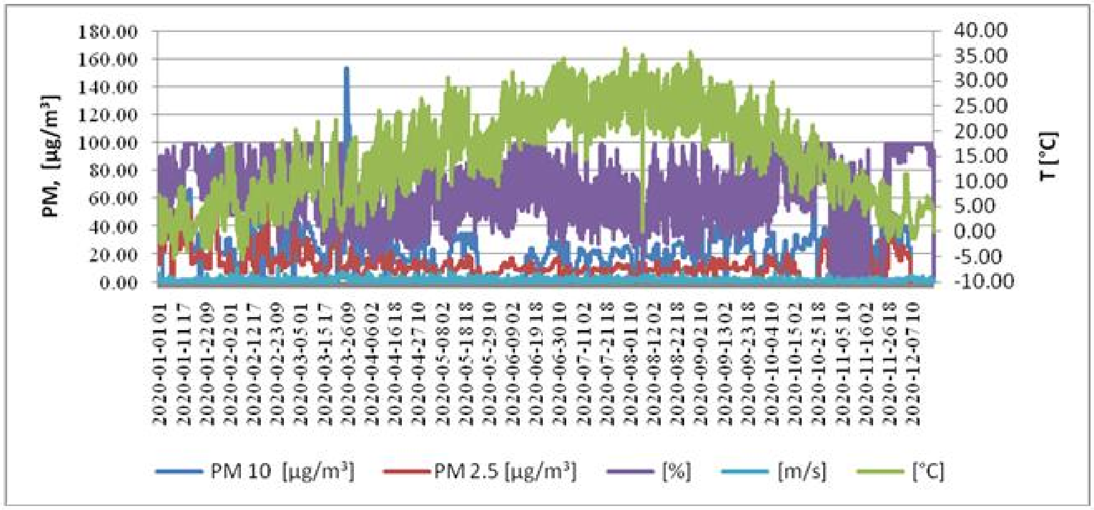
Pollutants do not act locally, in the emission area, they are transported in space, in the air, in surface waters, in groundwater, in the soil, affecting living conditions.

Placing vegetation barriers near a road increases the amount of vegetation deposition [7].



a)

Fig. 1a. Hourly values of PM 10 and PM 2.5 relative humidity, air temperature and wind speed recorded in the period 01.11-08.11. 2020 in Bucharest, Romania



b)

Fig. 1b. Hourly values of PM 10 and PM 2.5 relative humidity, air temperature and wind speed recorded in the period 01.01-21.11. 2020 in Bucharest, Romania

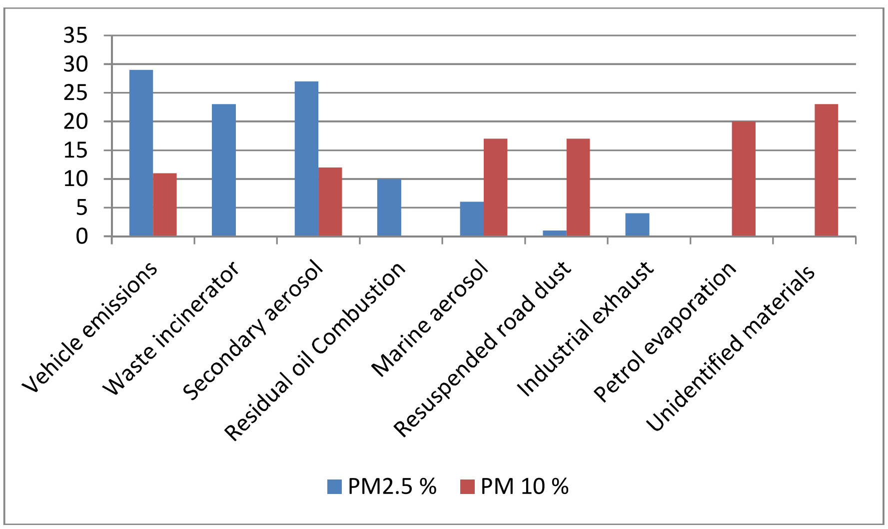
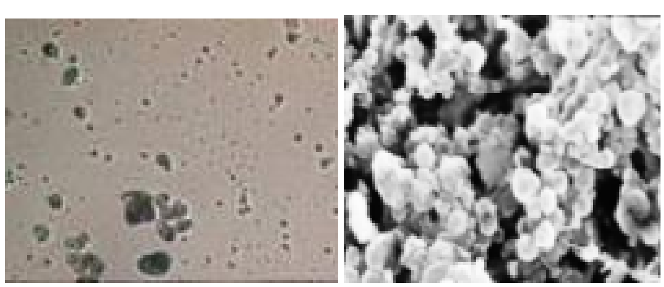
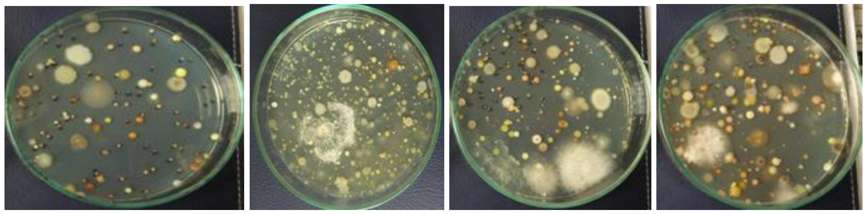


Fig. 2. Average mass concentrations of identified sources for PM2.5 and PM10 [19]



a b

Fig. 3. Structural aspects of material particles PM 10 and PM 2.5, [22]



a. hour 9 **b. hour 10** **c. hour 11** **d. hour 12**

Fig. 4. Determination of microbial load by sedimentation method

The leaves are the exposed parts of a plant, they can act as persistent absorbents in a polluted environment. Large-leaved species can provide effective barriers against coarse dust, but less effective barriers against finer dust that travel longer distances. The effects of pollutants vary depending on the type of generating anthropogenic activities and the topoclimatic characteristics of the environment [21]. Pollution caused by road transport on vegetation results primarily from changes in soil chemistry, composition or foliar chemistry. The impact on the vegetation occurs 1 km from the road due to the rapid dispersion of air pollutants of vehicles. Pollutants from traffic have suppressed leaf growth [22].

In Fig. 3 presented by optical microscopy (a), and by scanning electron microscopy (SEM) (b), the structural aspect of the material particles PM2.5 fine points, the largest are the PM10 particles, is observed the predominance of fine microscopic particles [23].

The determination of the microbial flora in the air was performed by the sedimentation method which consists in the exposure of Petri dishes with solid culture medium (agar or blood agar) in the place where the determination is made. The number of plates and the exposure time depend on the degree of air contamination. Then the plates are incubated on a thermostat (at 37°C) for 24 hours and the increased colonies are counted. Air samples were taken in Petri dishes in front of the faculty, bacterial colonies were counted, and the results were according to Fig. 4. Period of air sampling: November 7, 2020, 9,10,11,12.

To calculate the number of germs present in a volume of air, the number of germs on the surface of the plate is transformed into the number of germs per volume of air. This is done using the following formula:

$$Numberofgerms / m^3 aer = \frac{A*10^4}{S*k}$$

Where: A = number of colonies developed on the surface of the culture medium
S = surface box Petri ≈ 64 cm^2
k = exposure time coefficient: 1 for 5 min, 2 for 10 min, 3 for 15 min
10000 = volume of air expressed in cm^3, comprising a number of germs equal to the number of germs exposed on an area of 100 cm^2
Pentru prelevarea probelor s-a așteptat 15 min → k = 3.

$$\text{number of germs} / m^3 air = \frac{A*10^4}{S*k} = \frac{116*10^4}{64*3} = 6041{,}16$$ for the Fig. 4a

$$\text{number of germs} / m^3 air = \frac{A*10^4}{S*k} = \frac{280*10^4}{64*3} = 14583{,}33$$ for the Fig. 4d

$$\text{number of germs} / m^3 air = \frac{A*10^4}{S*k} = \frac{312*10^4}{64*3} = 16250$$ for the Fig. 4c

$$\text{number of germs} / m^3 air = \frac{A*10^4}{S*k} = \frac{540*10^4}{64*3} = 28125$$ for the Fig. 4b

The results obtained from the sampling of air do not reveal a very large exceedance of the normal limits, as it results from a comparison with the usual values of the number of colony-forming units (<550 UFC / m^3). The total number of germs (NTG), expressed in CFU / m^3, recorded the highest values for 10 AM, the density of microorganisms eliminated being proportional to the degree of agglomeration, long exposure time, but also the presence of air currents generated by movement or various physical activities of people existing in the area, increasing the degree of humidity. The microbial load was identified with Pseudomonas aeruginosa, they were between 10-40 CFU/m ^{3}.

4. CONCLUSIONS

In this paper was followed the impact of pollution with material particles PM 2.5 and PM 10 on vegetation, it was found, the increase in the number of trees showing symptoms of defoliation at 200 m from a road with 10,000-15,000 vehicles / day, decreased leaf pigment. In the desert environment, dust loads of 40 g m^{-2} increase the temperature of the leaves by 2 to 3^oC [7].

The presence of dense vegetation, close to the source of pollution improves air quality by increasing the absorption of pollutants. Coarse particle deposition is more efficient at high wind speeds, while the opposite is true for ultrafine particles. Vegetation reduces wind speed, leading to increased particle concentrations.

Tall oaks and cedars planted 25 m from a road, reduced by half the concentrations of PM10 and PM2.5, the tall grass in the pasture was reduced by 35% [7].

A barrier of 100 m of sparse vegetation reduces PM10 concentrations by 10% and 17-25 µm particles by 25%. The presence of vegetation leads to a decrease of material particles by 27.7%, through the absorption of material particles by plant leaves [8,16].

According Fig. 1a meteorological parameters influence the level of particulate pollution, in conditions of high temperature, clear sky, low wind speeds, relatively high humidity, PM 10 and PM 2.5 concentrations increase, as others authors said, [19,24].

The results obtained from air sampling do not reveal a very large exceedance of the normal limits, as it results from a comparison with the usual values of the number of units forming colonies (<550UFC / m^3). The total number of germs (NTG), expressed in CFU / m^3, recorded the highest values for 10 am, the density of microorganisms eliminated being proportional to the degree of agglomeration, long exposure time, but also the presence of air currents generated by movement or various physical activities of people existing in the area, increasing the degree of humidity. The microbial load was identified with Pseudomonas aeruginosa, they were between 10-40 CFU / m^3.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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