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"Gheorghe Asachi" Technical University of Iasi, Romania

PARTICULATE MATTERS GENERATED BY CAPRISOARA TAILING POND AND THEIR IMPACT ON AIR QUALITY

Adrian Florea*, Csaba Lorint, Ciprian Danciu

University of Petrosani, Faculty of Mining Engineering, Romania

Abstract

Analyzing and reducing the possible effects of air pollution on human health became important issues for improving the quality of life in urban areas. Particulate matters (PM) are air pollutants with a potential important impact on the health of vulnerable people (e.g., children, elderly) and non-vulnerable people as well. The level of PM air pollution is mainly influenced by the PM concentration and by parameters such as the meteorological conditions and the synergic effects of other air pollutants. Different clime scenarios have been developed to model the PM dispersion generated by the Caprisoara tailing pond, which stores the ashes from the Paroseni thermal power plant, and the effect on city Vulcan from Jiu Valley, in the Meridional Carpathian Mountains. The PM dispersion was simulated using the METI-LIS version 2.03 (Ministry of Economy, Trade and Industry – Low rise Industrial Source dispersion model) – a software developed under the funding of the Japan Ministry of Economy, Trade and Industry and the Research Center for Chemical Risk Management from Japan. The dominant direction of the winds in the Vulcan area is west, west-north-west, therefore the contribution of the Caprisoara tailings pond to PM generation in Vulcan is limited to periods when the wind blows from south, south-south-west, with an above average intensity in the conditions of a turbulent atmosphere, which happens during the summer. A cheap solution to minimize the displacement of fine particles is to maintain permanently a layer of wet material on the top of tailing pond.

Key words: air quality, METI-LIS, particulate matter dispersion, power plant ash, tailing pond

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1. Introduction

Particulate matter (PM) is a key indicator of air pollution brought into the air by a variety of natural and human activities. As it can be kept for a long time and spread on long distances in the atmosphere, it can cause a wide range of diseases, leading to a significant reduction of human life expectancy (Kim et al., 2015). Recent findings showed that about 20% or less of the coarse particles (10 μm) would penetrate through the extra thoracic airways and into the lower respiratory tract. A lower diameter of the PMs determines a higher impact on the health of vulnerable persons (e.g., children, persons with respiratory and cardiovascular diseases and elderly people) (Oprea et al., 2017). A recent study (An and Yu, 2018) examines the impact of ambient fine particulate matter ($PM_{2.5}$) air pollution on the health of college students in Beijing, China and another study (Karri et al., 2018) identifies the influence of the outdoor PM on the indoor PM using a genetic programming-based methodology.

The assessment of the impact of the industrial activities is important for protecting the population health and the environment while the continuous improvement of the working methods can make this complex process more accessible, more effective and more efficient (Bertolotti et al., 2014; Rada et al., 2016; Riffault et al., 2015; Torretta et al., 2015). Generally, an environmental analysis has the following objectives: the assessment of the current status of environmental components; the assessment of local and temporal tendencies; the assessment of

* Author to whom all correspondence should be addressed: e-mail: adrianflorea@upet.ro; Phone: + 40 722428105; Fax: +40 254543491

pollution sources; the measurements done to estimate potential risks and environmental impact (Capsa et al., 2016; Kovacs et al., 2014).

The mining industry in Jiu Valley had and still has a significant influence on the pollution of environmental factors, both by the discharge of noxious substances into the atmosphere and the large quantities of waste produced, as well as by their variety. Air pollution is a complex phenomenon involving a multitude of pollutants that can cause alterations of the population health and of the environmental quality, depending on concentration or duration, causing serious effects, acting either through high concentrations for a short period, or through reduced concentrations for a long period (Călămar et al., 2017).

The following concepts are frequently used in the field of air protection:

- Emission (discharge of contaminants into the free atmosphere by an emitter);
- Transmission (spatial distribution of impurities in the free atmosphere);
- Immission - the transfer of pollutants from the atmosphere towards a receiver (population and factors of its ecological system, property etc.) (Kovacs et al., 2014).

The joint of these phenomena (emission – transmission - immission) refers to all the processes that lead to a change or dilution of the polluting agents in the air (Ştefan et al., 2013). They have a direct effect on immission and basically consist in the measurements of pollutant concentrations, of local weather conditions, secondary emissions etc. (Irimie and Petrilean, 2013; Prorocu et al., 2014).

The main objective of the paper is to assess air quality in terms of dust from the vicinity of the city Vulcan from Jiu Valley by evaluating the particulate matter dispersion from Caprisoara tailing pond in various meteorological scenarios using METI-LIS software. Currently the measurements are carried out by the Hunedoara Territorial Environmental Agency through a monitoring station, located in Vulcan.

After the description of location and characteristics of the tailing pond, a chemical and granulometric analysis of the ashes determined on six samples is presented. Next, there are presented the steps taken to achieve the PM dispersion modeling using METI-LIS software and then the results and conclusions of the paper.

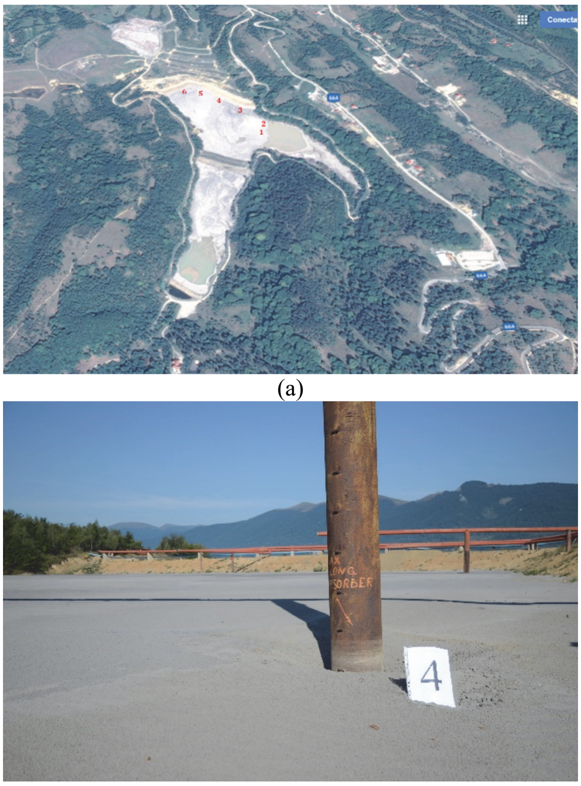
2. Material and methods

2.1. The nature of pollutants

Particulate Matter 10 (PM_{10}) is the general term used for solid particles and liquid droplets in the atmosphere with a maximum diameter of 10 microns. PM_{10} may result from several natural and anthropogenic sources and is a major air pollutant in urban areas. The EU limits for PM_{10} concentration in ambient air are frequently exceeded (EEA, 2013). The PM_{10} concentration has effects on human health and biosphere but also on cloud formation and radiation package of the earth-atmosphere system. This may cause changes in time, affecting the atmospheric circulation, surface temperature and precipitations.

The maximum accepted values for PM_{10} in the European Union are: the annual mean - 40μg/m^3, the short-term maximum values - 50μg/m^3 for 24-hour average and shouldn't be exceeded more than 35 times a year, according to the Directive 2008/50/EC (EC Directive, 2008).

In order to evaluate the nature of the pollutants, we collected a total of six samples (Fig. 1a) from different points of Caprisoara tailing pond (Fig. 1b) and made the chemical and granulometric analysis of the ashes. The location of the probing points was chosen in order to have an overview of the ashes deposited in the tailing pond but also to have an easy access for sampling. Caprisoara tailing pond is located near the city Vulcan from West Jiu Valley, in the Meridional Carpathian Mountains and stores the ashes from the Paroseni thermal power plant. At this time, among the five tailing ponds only two are active, the emergency tailing pond and Caprisoara tailing pond. The Radon tailing pond (surface 10 ha) was used last time in 2006 because it is already full. The Ijak (surface 8 ha) and Feres (surface 10 ha) tailing ponds are closed, refurbished and partially covered by natural revegetation.



(a)

(b)

Fig. 1. Caprisoara tailing pond: a) location of sample points; b) sample point no.4

The active tailing pond now is Caprisoara with a surface of 48 ha and 5 320 000 m^3 storage capacity out of which 1 790 000 m^3 is already filled and 3 530 000 m^3 is available.

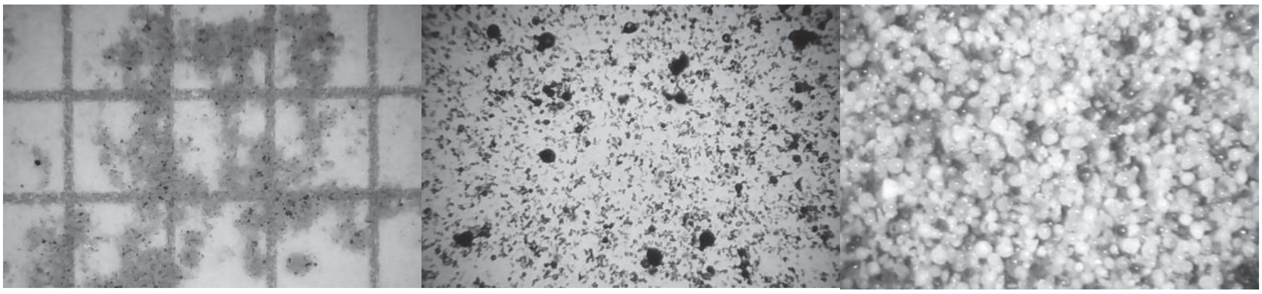
A Rigaku benchtop total reflection X-ray fluorescence (TXRF) spectrometer was used to establish the chemical composition of ash, the results are presented in the Table 1. The aspect of ashes and the granular structure can be seen in the pictures taken through a microscope (Figs. 2, a, b, c). The dimension of squares in the Fig. 2a is 1×1 mm. It can be seen that the shape of the particles is closer to spherical form.

The granulometric analysis of the six samples (Fig. 3a) was done according to STAS 1913 / 5-85, by sieving and sedimentation. For particles larger than 0.063 mm, the granulometric analysis was performed by screening (Fig. 3b) and for particle sizes smaller than 0.063 mm, the granulometric analysis was performed by sedimentation (Fig. 3c).

Based on the results obtained, the granulometric curve was plotted for the six samples of ash, collected from Caprisoara tailing pond (Fig. 4). As we can see, three of the samples (sample no. 1, 2 and 3) contain also fractions smaller than 0.01 mm while the samples no. 4, 5 and 6 contain exclusively fractions bigger than 0.01 mm. The first three samples were collected from an area where the deposition of slurry was more recent while the last three samples were collected from an area with older slurry deposition. We assume that for the last three samples, the lack of fine fraction is due to their displacement done by the wind and by the water from precipitations.

Table 1. Chemical composition of ash from Caprisoara tailing pond

Parameter	***Value [%]***	
	class +0.063 mm	***class -0.063 mm***
MgO	0.7788	0.6451
Al_2O_3	24.3836	23.6005
SiO_2	57.3223	57.5692
P_2O_5	0.0751	0.1364
SO_3	0.4135	0.9547
Cl	0.0257	0.0472
K_2O	8.0245	7.5681
CaO	4.6563	5.7470
TiO_2	0.7828	0.3056
Fe_2O_3	1.9470	2.5376
NiO	0.0000	0.0014
ZnO	0.0000	0.0067
GeO_2	0.0293	0.0234
As_2O_3	0.0071	0.0064
SeO_2	0.0005	0.0003
SrO	0.0000	0.0054
ZrO_2	0.0000	0.0375
MoO_3	0.0070	0.0000
CL	0.9953	0.1491



(a) (b) (c)

Fig. 2. Microscopical view of ashes from Caprisoara tailing pond:
(a) general view in dry stage (KRUSS Microscope); (b) aqueous solution view (LEICA Stereomicroscope); (c) details of 0.063-0.16 mm particle size class (Binocular magnifying glass Tehnival)

(a) (b) (c)

Fig. 3. Granulometric analysis of the six samples of ashes from Caprisoara tailing pond:
(a) samples prepared for granulometric analysis; (b) screening process for particles larger than 0.063 mm;
(c) sedimentation process for particles smaller than 0.063 mm

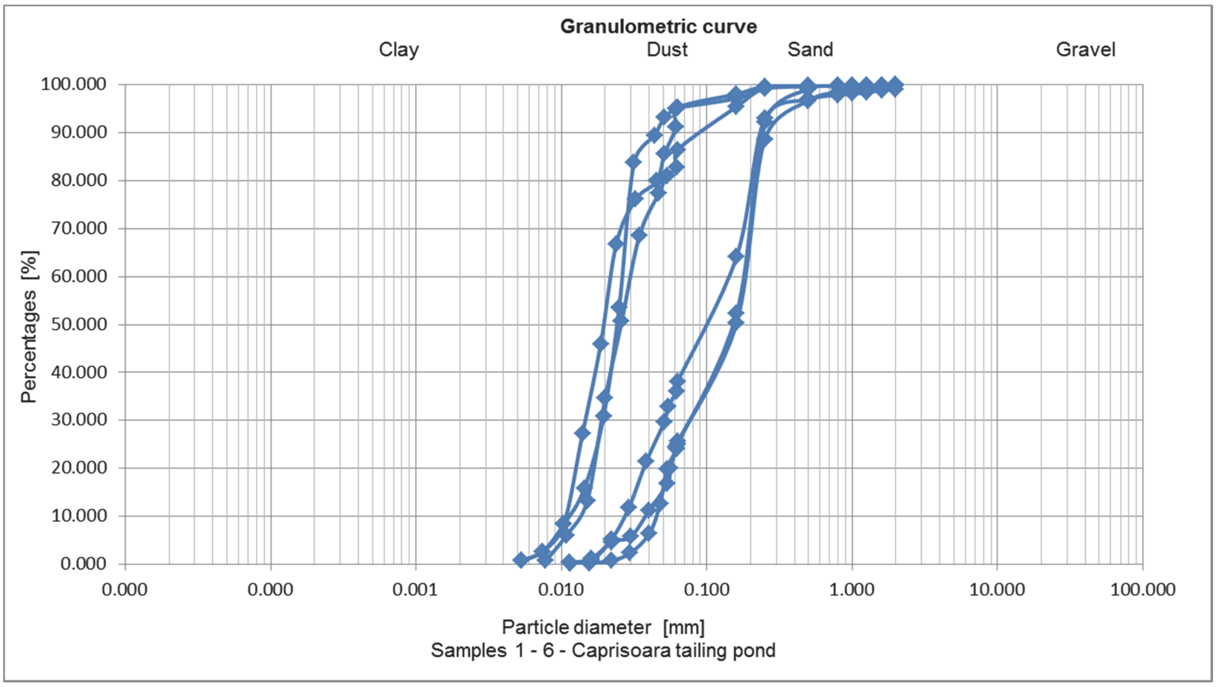


Fig. 4. Granulometric curves for samples 1 to 6, taken from Caprisoara tailing pond

2.2. Dispersion modeling of particulate matters

An atmospheric dispersion model is a mathematical expression relating the emission of material into the atmosphere to the downwind ambient concentration of the material. The purpose is to estimate the concentration of a pollutant at a particular receptor point by calculations, using basic information on the source of the pollutant and on the meteorological conditions.

In the present study, the PM_{10} concentration was simulated using the METI-LIS version 2.03 which is a Gaussian dispersion model developed on the basis of the ISC model of the U.S.EPA. In 1996, the Ministry of Economy, Trade, and Industry (METI - Japan) has developed and used this model, when the air contamination issues were included in the Air pollution prevention Act in Japan. The research comparison shows that the performance of the model is better than that of the original ISC model (Torabi and Nogami, 2016).

This program can make simulations for two types of atmospheric pollutant sources, point sources and linear sources. The simulation method designated in our study was for linear sources. Mandatory input data are: emission rate, other emission condition such as the location and terrain morphology and meteorological data (wind direction, wind speed, temperature and atmospheric stability class) (Dragomir et al., 2014). Sources with line-shaped characteristics are calculated in the model by numerically integrating the point source plume equation (Dragomir et al., 2015). In order to proceed with dispersion modelling, we realized a screenshot from Google map after selecting a suitable area on display and we defined the pollution source as a linear one, along the longitudinal axis of the two branches of the tailing pond and a receptor network of points. The dimension of the receptor network is 83×56 points which covers an area of 8200×5500 m and the height of receptor was set to 1 m (Fig. 5). For proper terrain morphology, we defined the elevation of each point from this network in a .csv file with 56 rows and 83 columns, as it is described in the METI-LIS operation manual (METI, 2005), based on the level curves displayed by activating the option terrain in Google map. The minimum terrain altitude in this rectangle of 8200×5500 m is 590 m and the maximum terrain altitude is 1280 m.

3. Results and discussion

After all the preliminary tasks were done, we started running different scenarios with different conditions, in order to analyse the dispersion models and the impact on the city Vulcan nearby. Since the dispersion phenomenon of PM occurs during the dry periods of the year, especially in the summer, and Vulcan is a town in a mountainous area, we considered an average air temperature of 15ºC. We followed the phenomenon of dispersion of PM under the same temperature and atmospheric stability class for wind with the same intensity but blowing from different directions, then under the same conditions of temperature, intensity and direction of the wind but for different classes of atmospheric stability and then under the same temperature conditions, atmospheric stability class and wind direction but wind blowing with different intensities. In the first scenario we considered air temperature 15ºC, wind speed 5 m/s, stability class A, and wind direction ENE (Fig. 6a), SSE (Fig. 6b), SSW (Fig. 6c) and WSW (Fig. 6d). As it can be seen, in the last three cases the ashes blown away by the wind reach the town Vulcan.

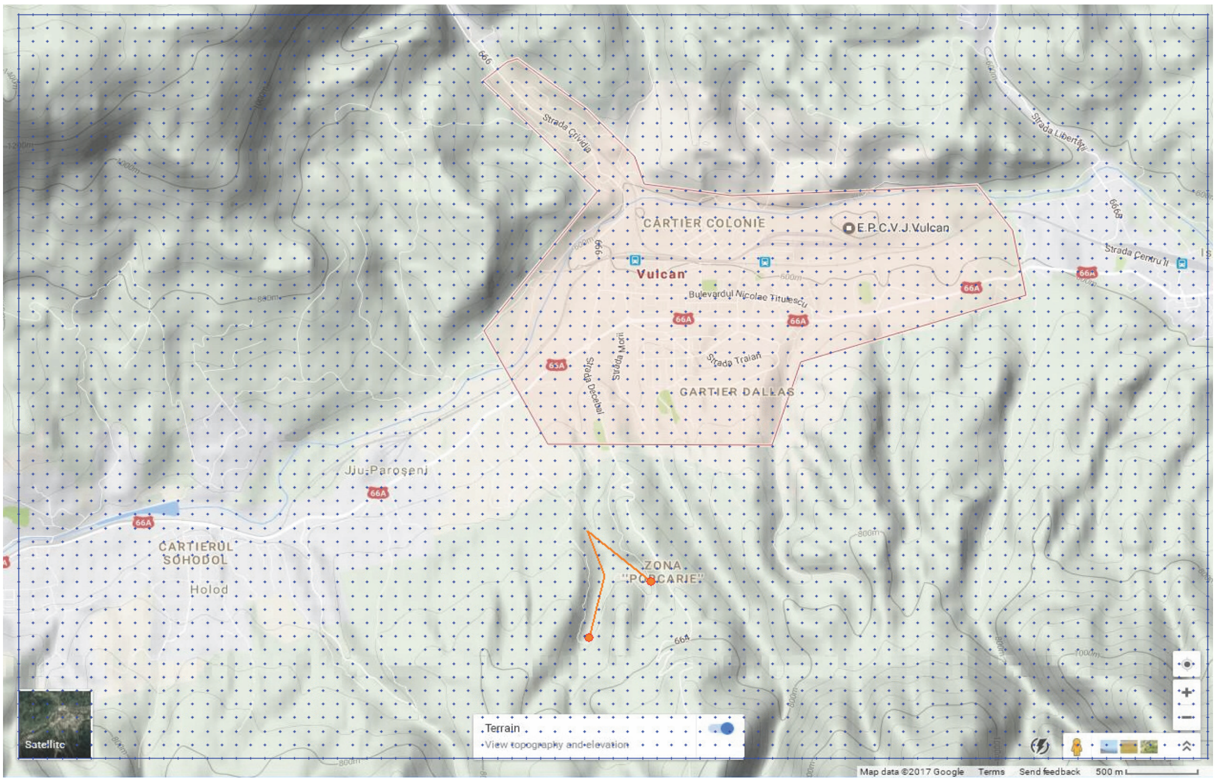
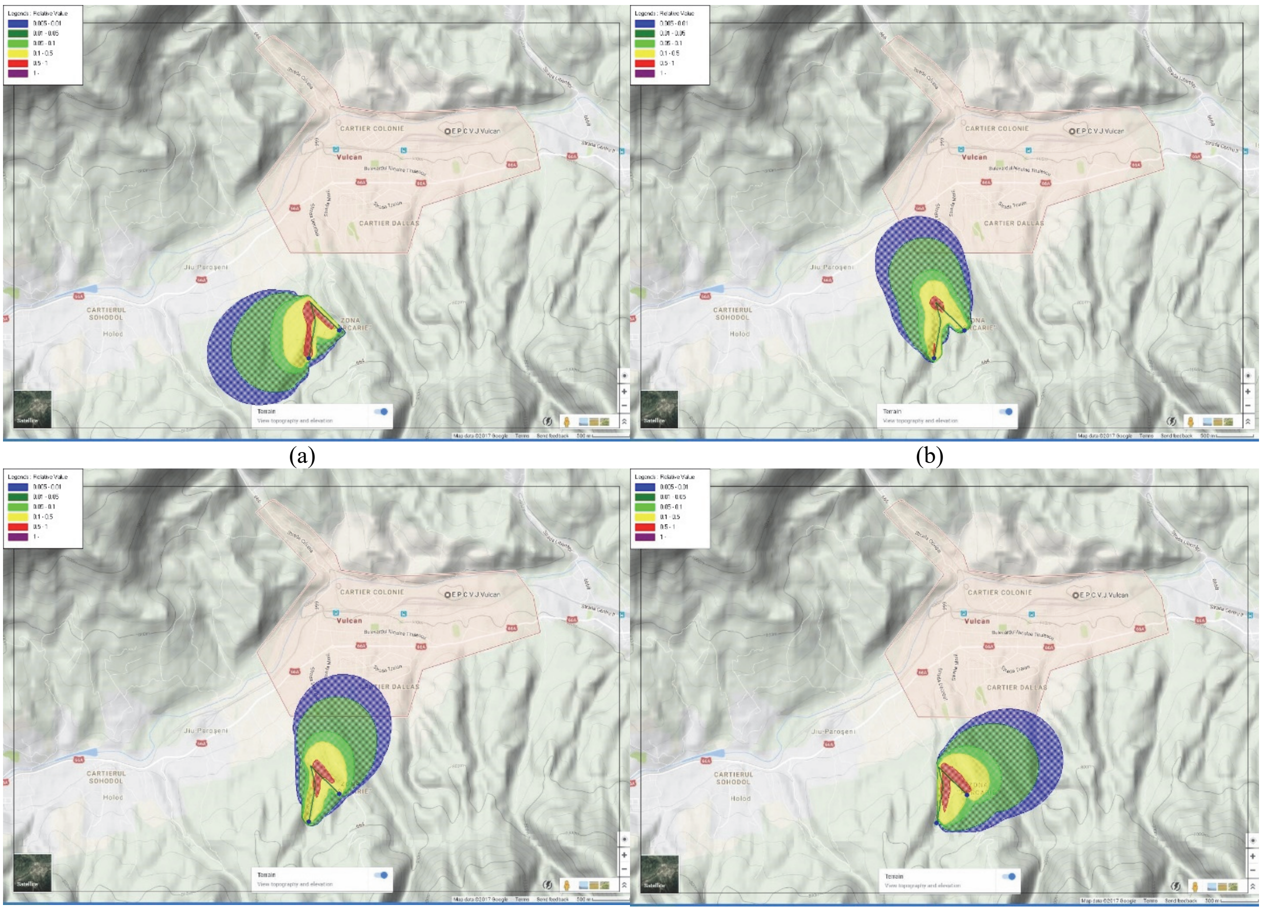


Fig. 5. Google map screenshot of Caprisoara tailing pond and surroundings with the level curves, the linear pollution source and the network of receptor points



(a) (b) (c) (d)

Fig. 6. Dispersion models of particulate matter from Caprisoara tailing pond (in relative values) in the same clime scenario (air temperature 15ºC, wind speed 5 m/s, stability class A) but different wind directions: (a) ENE, (b) SSE, (c) SSW, (d) WSW

In the second scenario we considered air temperature 15ºC, wind speed 5 m/s, wind direction SSW, and stability class A (Fig. 7a), C (Fig. 7b), and DN (Fig. 7c). As it can be seen, in case of same wind speed and direction, if the atmosphere becomes more stable, the dispersion phenomenon slows down and, as a result, the affected area is larger. In the third scenario we considered air temperature 15ºC, stability class A, wind direction SSW and wind speed 5 m/s (Fig. 8a), 10 m/s (Fig. 8b), 15 m/s (Fig. 8c), and 20 m/s (Fig. 8d). As it can be seen, in the case of same wind direction, the dispersion phenomenon accelerates when the wind speed increases.

The PM measurements made in Vulcan recorded an average value of 19.27μg/m^3 in August 2015 and 23.51μg/m^3 in November 2015 (Călămar et al., 2017). Given that PMs come from multiple sources and that the dominant direction of the winds in the Vulcan area is west, west-north-west, the contribution of the Caprisoara tailings pond to PM generation in Vulcan is limited to periods when the wind blows from south, south-south-west with an above average intensity in the conditions of turbulent atmosphere, which happens during the summer storms.

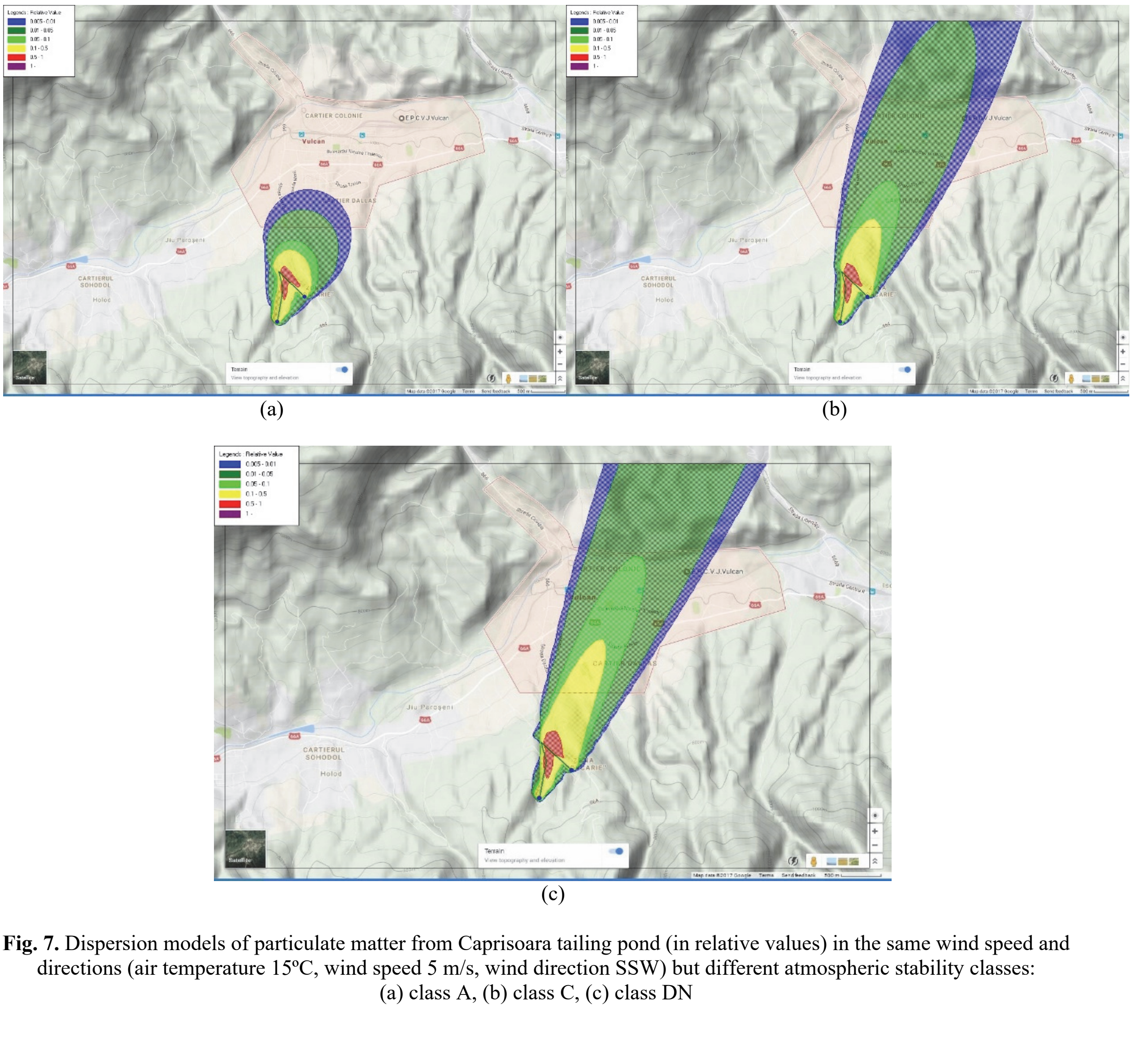
4. Conclusions

The lack of fine fraction in the samples no. 4, 5 and 6 collected from an area with older slurry deposition is due to their displacement done by the wind and by water from precipitations. The vegetation surrounding the Caprisoara tailing pond is covered in dust in some summer days.

Given that the dominant direction of the winds in the Vulcan area is west, west northwest, the contribution of the Caprisoara tailings pond to PM generation in city Vulcan is limited.

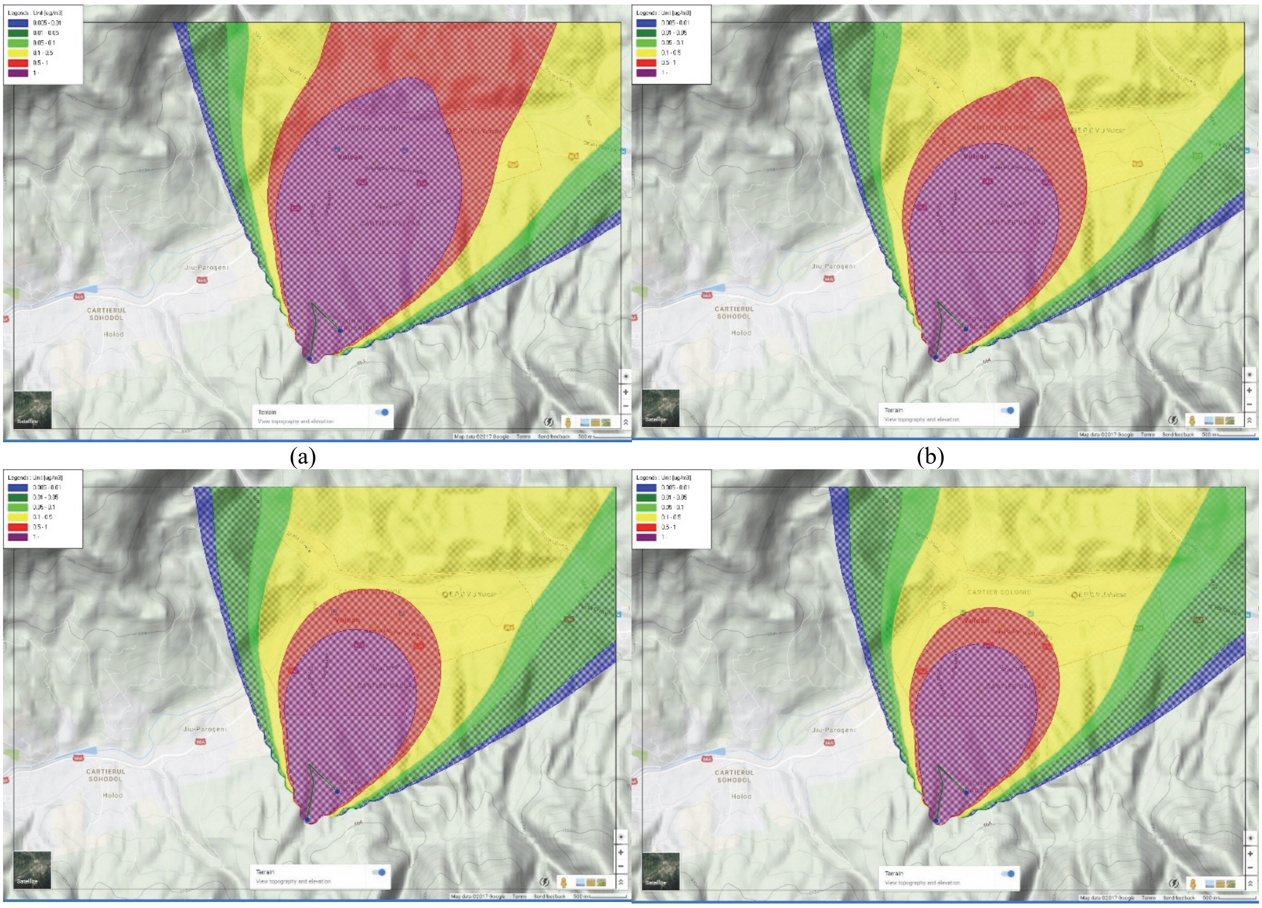
The displacement of fine fraction by the wind is favoured by dry periods, usually in summer time. If the wind direction is from south, south-south-west the fine particles reach the city Vulcan but if the wind blows from another direction, the fine particles cover the vegetation surrounding the tailing pond. If the atmosphere becomes more stable, the dispersion phenomenon slows down and, as a result, the affected area is larger.

The dispersion phenomenon accelerates when the wind speed increases, but the areas with same pollutants concentration are smaller.



(a) (b) (c)

Fig. 7. Dispersion models of particulate matter from Caprisoara tailing pond (in relative values) in the same wind speed and directions (air temperature 15ºC, wind speed 5 m/s, wind direction SSW) but different atmospheric stability classes: (a) class A, (b) class C, (c) class DN



(a) (b) (c) (d)

Fig. 8. Dispersion models of particulate matter from Caprisoara tailing pond (in absolute values) in the same stability class and wind directions (air temperature 15ºC, stability class A, wind direction SSW) but different wind speed: (a) 5 m/s, (b) 10 m/s, (c) 15 m/s, (d) 20 m/s

A solution to minimize the displacement of fine fraction is to maintain permanently a layer of wet material on the top of tailing pond also in dry periods, because the geographical location of the tailing pond ensures most of the time a top layer of wet material in a natural way.

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