Study of Physico-Chemical Characteristics of Some Major Urban Air Pollutants

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Abstract. Urban air/environmental pollution as a major concern of contemporary civilization, substantially affecting the health of the residents, requires identification of both physico-chemical specificity and generating sources. Particle matter (PM) monitored in the atmosphere should be associated to their chemical composition that allows identification of sources as enhancement contributor and sinks as mitigation factor but also as possible spreading agent as it has been reported in rain fall for some of the pollutants categories. After a number of episodes of increased amounts of measured PM 2.5 and PM 10, considerable dust deposits on cars were collected and SEM-EDX analyses were performed, showing the agglomerated morphology and elemental composition of the dust. Sodium aluminate and calcium chloride were identified as major contributors to the dust composition. Such chemical components may end-up into the water supply and tap water as previously reported affecting the quality of the water. As sources, dust-binding solutions for streets cleaning and/or coagulant agents in constructions are to be considered.

1. Introduction
Urban pollution is mainly associated to the highly intense car traffic, with emission of oil combustion chemical compounds in gas, liquid or solid state contaminating the air [1-5], the soil and waters in a circuit that has been called as “atmosphere self-cleaning” [6] or “wet removal” [3, 7] and the connection of the atmosphere composition with the components deposited on soil has been proven when rain water was analyzed after an abundant rainfall episode following to a drought period of time [6, 8]. Pollutants of organic origin specific to result from fuel combustion, including soot that has being intensely studied due to its negative impact on the environment quality, proved to be a serious matter for the environmental issue as contributors to the particles inducing respiratory disorder [9-14], including from the perspective of particles PM 10 that are sourced both in smoke and dust [15-17].

Assimilating an existing technology of using coagulants or flocculants for cleaning the waters of organic dispersed contaminants [18-21], but also in dust control applications [22], some municipalities have started to apply the procedure for a dry – cleaning process of the streets [23]. The method is
known as “dust – binding” and it consists in using “calcium chloride liquid solutions” to reduce streets dust emission. Helsinki municipality, after a study in the REDUST Life + project in 2011-2014 as to the cost – effectiveness impact, has used the cleaning procedure, but also Seoul and others. However, problems that may arise from the use of one or the other of the coagulants or flocculants require careful approach and this is the aim of the study presented herein.

During winter time, within 13 – 15 January 2020, the quantity of dust on the streets of Iasi was obviously more than usually. On the cars driving in the traffic of Iasi City, a consistent layer of dust was noticed too. The situation was unusual, such episodes of dusty environment being specific only for when construction activities are carried out in a certain area, or when antiderapants such as calcium chloride mixed with sand are used. In the same period of time, IS1 Monitoring Station of Romanian Environmental Protection Agency (APM – Agentia de Protectia Mediului) measured high levels of PM10.

2. Methods of investigation
After collecting dust from the surface of the car, the sample was analyzed using Scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS) as morphology and elemental composition. Evaluation of the dust origin was performed based on the PM10 and benzene levels registered in the atmosphere in the period of time between 13 – 15 January 2020, and their compared variation at different times.

3. Results and discussions
3.1. Scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS)
Morphological aspect observed in Figure 1(a) denotes agglomerated structures consisting in granular/spherical, fusiform, fibrous and acylar shapes with dimensions varying between less than 150 μm to over 1400 μm (1.4 mm) for granular structures while fibrous/fusiform structures show dimensions over 2000 μm (2 mm) length, as seen in SEM image presented in Figure 1 (a - d).

![SEM images of dust sample of different magnitude: 45 x (a); 100 x (b), (c), (d).](image-url)
Even from the images with magnification orders of 45 x and 100 x, an aggregation and/or flocculation structure had been observed (Figure 1 (a - d)). In the SEM image of magnifying order 400 (Figure 1 e), the micro-composite structure of each of the granular and fibrous elements seen in the images of Figure 1 (a – d) is clearly identified. The aggregate particles in the composite structures are spheroids and flakes of average sizes from 10 μm to 40 μm in diameter. Based on elemental composition (Table 1), there is evidence about the presence of so called “dust –binders”, known as coagulants or flocculants in physico – chemical processes. Such binders provide a micro – continuous phase that is used in water cleaning and recently on dust – cleaning to enhance the particles size the desired effect being to make the particles filterable when cleaning the water or to keep them on soil when it is about dust cleaning.

![Figure 1](image1.png)

**Figure 2.** Maps with elemental distribution on a segment of sample of 400 μm: a) Al; b) Na; c) Ca; d) Cl; e) Si; f) O.

Analyzing the elemental composition (Table 1) and elements distribution (Figure 2) performed with energy dispersive spectroscopy (EDS), the flocculent agents, namely sodium aluminates, NaAlO$_2$, Na$_2$O-Al$_2$O$_3$, or Na$_2$Al$_2$O$_4$ or their alkali form in solution, NaAl(OH)$_4$ are denoted, while as for coagulant agents there are indications of calcium chloride, CaCl$_2$, as well as sodium chloride, NaCl. These binding agents develop continuous phase in solution contributing to binding the organic and inorganic particles. Flocculation develops fibrous and acylar formations that are usually attributed to organic components denoted by carbon detected in elemental composition bound with sodium aluminates [6, 24]. Coagulation develops the granular shapes and represents the binding with CaCl$_2$ of the sand particles denoted by the silicon from the elemental composition [22].

| Element | Mass [%]  | Atom [%] |
|---------|-----------|----------|
|         | (1)       | (2)      | (3)      | (1)       | (2)       | (3)       |
| Oxygen  | 48.91558  | 42.10785 | 52.24393 | 64.19317  | 50.53882  | 62.26211  |
| Carbon  | -         | 13.17617 | 7.802855 | -         | 21.06569  | 12.387    |
| Silicon | 18.13641  | 11.64905 | 18.28044 | 13.55859  | 7.964786  | 12.4107   |

**Table 1.** Elemental composition of the dust sample.
3.2. PM10 and benzene analysis
Following the data of the measurements registered by IS1 Monitoring Station of Romanian Environmental Protection Agency (APM), during a period of time when the Municipality of Iasi announced the dust – binding procedure to be used for streets cleaning, and when the most dust was deposited on the cars during traffic or while parking, few aspects are to be noticed. As previously discussed, EDS analysis proved presence of the “binders” as sodium aluminate and calcium chloride, and their effect was noticed in the SEM images as agglomerates and micro-composite structures. The data from IS1 Monitoring Station represented in the plot of Figure 3 show 5 μg/m³ PM10 and 9 μg/m³ benzene on January 13, 2020 at 10 am hours, while starting with 12 am hours of the same day, the PM10 concentration in air versus benzene changes, meaning that there is a sudden growth in PM10 measured (8 μg/m³) compared to benzene (6 μg/m³).

From that time until January 15, 2020 at 6 pm hours the concentration in PM10 is the predominant one. It could be in relation with the dust – binding process during cleaning performed on the streets of Iasi, meaning that solution of dust – binders had been administrated on the streets on January 13, 2020. Another source of sodium aluminate on the streets could be from constructions activity where the
flocculent agent is used in cements for a fast binding of the composite. However, such activity was not in the area. As for calcium chloride, it is also an anti-skid agent, used during winter when mixed with sand. However, the explanation for the IS1 Monitoring Station data measurements may be in absorbing and/or binding the benzen with sodium aluminate, more than the measured values are very close for PM10 and benzene and identical in some points like on January 13, at 6 pm hours, or on January 14, at 9 am hours.

As SEM images show, the 10 μm particles are bound in micro-composite structures due to flocculation and/or coagulation and are kept on the soil but if they are not removed, the micro-composites are crushed due to their low mechanical strength under compression during traffic. Advanced drying of the dust formed composite could be also a cause for the crushing because water is one of the key elements in the flocculation and coagulation process.

4. Conclusion and perspectives
The streets pollution with flocculent and coagulant agents either used with the aim of “keeping the dust at soil”, has been proven with the study presented herein as being inefficient due to the low strength of the bindings within the micro – composite structures which are crushed during mechanical actions or by dehydration of the aggregate components involved. That resulted in a high level of the PM10 dispersed in the air and the particles carry organic components such as benzene detected at very close level with PM10 by IS1 Monitoring Station which denotes benzene binding on the particles.

It is obvious that the dust – binding without proceeding with vacuum cleaning after that is not a reliable environmentally safe process to be used on the streets of the cities.

If the binding agents arrived on the streets either accidentally from construction or from use as anti – skid agents, the same immediate vacuum cleaning is required to prevent grinding the micro – composite back into dust - like particles that are trained in the air.

5. References
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