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A study of outdoor dust in city of Gyumri, Armenia

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Abstract

This particular research covered the territory of the second biggest city of the Republic of Armenia - Gyumri. The city lies within a seismically active zone. Strong earthquakes that occur there periodically, affect social and economic conditions and environmental status. A recent devastating one occurred in 1988 almost completely ruined the city. Present-day Gyumri has been re-built partially, nonetheless numerous dust sources and natural and anthropogenic factors are detectable there that significantly contribute to dust pollution. The research goal was implementing the first post-earthquake assessment of outdoor dust pollution levels in Gyumri employing different methods. The sampling through regular grid (wholly 22 spatially coherent sampling sites) was implemented in August-September 2013 by different methods (indication environment (leaf), direct instrumental sampling (aspiration)) which allowed determining daily dust load (kg/sq.km) and dust content (mg/m^3). Maps produced to reveal and collate peculiarities of spatial distribution of dust load and dust content helped contour the dustiest parts of the city. It is noteworthy that 2 peaks in dust loading were established in the west of the city, this disagreeing with those in dust contents. At the same time MAC - exceeding dust contents were detected throughout the city. It is noteworthy, too, that for the studied period dust contents in the city outskirts remained low and were not excessive against MAC. This means that dust accumulates mostly in the main residential district of the city. The assessed dust pollution levels allow concluding that dust is one of prior pollutants of atmospheric air in city of Gyumri and therefore is an environmental and health risk factor to the local population.

Keywords: Urban air pollution; urban dust; dust load; dust content.

1. Introduction

Cities which suffered earthquakes largely differ from other ones by quite a different nature of socio-economic, demographic, healthcare, urban development, and environmental problems and ways to their management. Presently, scarce research data are available on environmental pollution problems of cities which have suffered earthquakes. The available

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data commonly prove that earthquakes result in increasing radon emanation (Omori et al., 2007), increasing levels of dust (Yamamoto et al., 1999) and asbestos (Dimiskovska, 2010) pollution and induce changes in the quality of natural water streams as well (Liu et. al., 2007). Problems become apparent in the phase of reconstruction of destroyed cities and are aggravated in the case of a prolonged post – earthquake recovery.

A list of such cities includes Armenia's second biggest city - Gyumri with an area of 44.4 km² and population of 121,300 people. The city lies in a seismoactive zone, and strong earthquakes that occur there regularly alter socio-economic and demographic situation and environmental status. The most recent devastating event known as the Spitak earthquake of December 7, 1988 almost completely ruined the city. The post – earthquake recovery and reconstruction work has not been completed yet, and even today consequences of the earthquake are found throughout the city area (totally and partially collapsed buildings, lots of open landfills such as debris, glasswool waste, asbestos slate, garbage, etc.).

These adverse environmental consequenses are added by extensive reconstruction works, ground roads, operating industries, exploitation of different deposits and mines (tuff, clay and sand quarries), reduction of green areas all across the city. The city lies in a depression, enjoys a dry climate, the native landscape is steppe with sparse vegetation, strong winds are common. Such a combination of man-made and natural factors affects the quality of urban environment as a whole and atmospheric air in particular, becoming a cause of increasing atmospheric dust levels as well.

The research goal was implementing the first post-earthquake assessment of outdoor dust pollution levels in Gyumri employing different methods.

2. Materials and methods

This dust research was done through two different methods: indication environment (leaf) and direct instrumental sampling (aspiration). The indication environment method allows measuring dust load, while direct instrumental methods are employed to determine the content of suspended air dust. Sampling was done in August - September 2013, through a 1:100.000 scale regular grid. Sampling was spatially coherent and was done concurrently employing the both methods (Fig. 1).

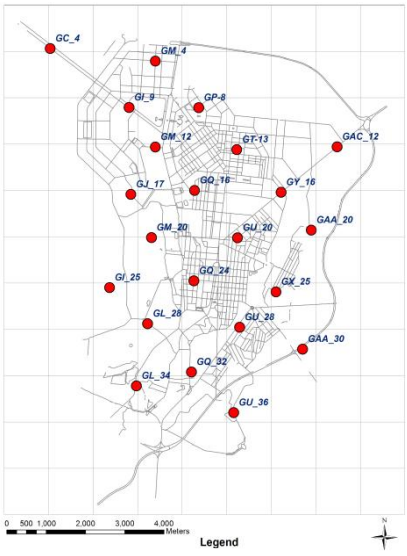

Fig.1. The map of sampling sites.

Tree leaves are known to be good indicators of dust (Ram et al. 2014), so the tree species studied were selected based on leaf dust accumulation property and their spreading throughout the city area. The studied tree species were maple ash *(Acer negundo)*, Chineese elm *(Ulmus parvifolia)*, white elm *(Ulmus laevis),* Persian walnut *(Juglans regia*), black locust *(Robinia pseudoacacia),* black poplar *(Populus nigra).* Leaf samples were collected from 20 out of 22 sampling points as two of the points lacked one of the selected tree species. Leaves were gathered at a max. height of 2 m above the ground, placed into paper bags and

transported to the lab. Dust from leaf surfaces was washed out by distilled water, the generated liquid was filtered. A dry residue was dried are weighed. Leaf dust load (P_{leaf}) was determined by formula (1)

$$P_{leaf} = (m_0 - 0.35 \cdot m_0) / S \cdot t \,, \quad (1)$$

where m_0 is mass of filtered substance, t is the quantity of days between the last rain and start of sampling, S is a total surface of leaf (Ilkun, 1978; Yerokhina, 1987; Belyaeva & Nersisyan, 2010).

Direct dust sampling was done by a short scheme through the accepted method applying an ABA-1-120-02A aspirator (RA Government Resolution, 2007). Highly efficient filters were used for capturing fine dust particles sized over 0.1 μm. Sampling points were spatially associated with leaf sampling sites. Wholly, 22 air dust samples were taken. The data obtained were then compared with Maximum Acceptable Concentration (MAC) accepted in the RA (RA Government Resolution, 2006).

Calculation of mean daily contents of dust which enter the human organism through inhalation was done by (2) formula, which expresses a daily share of an inhaled pollutant in mg per kg body weight. The pulmonary absorption of dust was assumed to be 100% (Hassanien et al., 2009). Also, it is supposed that air dust contents consist of inhalable particles (PM10).

$$I = C \times IR \times EF / BW \quad (2)$$

where C is air dust contents mg/m^3, IR – inhalation rate m^3/day (for child – 7,6, adults – 20 mg/m^3) (Van den Berg, 1995), EF – exposure factor (per day calculation (unitless), and BW – body weight in kg (for child – 15, for adults – 70kg) (US EPA, 2002).

Statistical analyses were done in the R program. Determined were descriptive statistical values of dust load and dust content. The Shapiro-Wilk test was used to verify normal distribution of preliminary and logarithmically transformed data. The Pearson correlation coefficient was determined (Reimann, 2008).

For revealing peculiarities of spatial distribution of dust load and dust content and zoning the area by pollution levels thematic maps were produced with help of ArcGIS program package. IDW was selected as an interpolation method. Gradation of dust load was done according to tabulated hazard and pollution levels (Perelman & Kasimov, 1999). Dust content was graded according to quotient by a 0,1 step.

3. Results and discussion

The descriptive statistical parameters of dust load and dust content are given in Tab.1. Both the fact that the value of mean is bigger than median values and positive skewness values prove a right-side asymmetry of dust load and dust content distribution. The latter argues abnormal distribution of data, this proved by results of the Shapiro-Wilk test, too (Tab. 2). According to the results of the Shapiro-Wilk test (Tab. 2) logarithmically transformed values of dust load and dust contents follow a normal distribution. A comparative analysis indicates that there exists a significant negative correlation (–0,513) of a logarithmically transformed value of dust load and dust content.

Studies of leaf dust load have indicated that dust load in samples varies 53,49 to 482,6 kg/km^2 daily, making 198,35 kg/km^2 on the average (Tab. 3). Mean daily dust load corresponds to low level of pollution. 70% of samples exhibited low levels, 15% - medium

Table 1. Descriptive statistical parameters of dust load and dust content values.

	Range	Mean	Median	SD	CV	Skewness
Dust content	0.035 - 0.962	0.22	0.17	0.20	0.91	2.65
Dust load	53.48 - 482.57	198.35	120.56	145.94	0.74	1.11

Table 2. The Shapiro-Wilk test results on statistical distribution of dust load and dust content.

Test of Normality Shapiro-Wilk			
	Statistic	df	Sig.
Dust content	0.69	22	0.000
Log_Dust content	0.96	22	0.508
Dust load	0.80	20	0.001
Log_Dust load	0.92	20	0.101

Table 3. Values of dust load and content, daily inhalation dose.

Value	Dust load (kg/km²)	Dust content (mg/m³)	Daily dust inhalation dose (mg/kg/day)	
			Child	Adult
Mean	198.35	0.22	0.11	0.06
Maximum	482.6	0.96	0.49	0.27
Minimum	53.49	0.03	0.015	0.0086

level and 10% - high level of dust load (Fig. 2a).

As indicated by the results of direct instrumental sampling, air dust content varies within 0.03 to 0.96 mg/m³, making 0,22 mg/m³ on the average (Tab. 3). In the case of lowest content no MAC exceeding values were established. Mean contents exceeded mean daily MAC (0.15 mg/m³) by 1,5 times, the highest content - mean daily MAC by 6,4 times and the maximal one-time MAC (0.5 mg/m³) by 1,9 times (Fig. 2b). In 60% of samples dust contents exceeded mean daily and in 9,5% – the maximal one-time MAC.

The results of mean daily inhaled intake of dust indicate that child inhales min. 0.015 mg/kg/day and max. 0.49 mg/kg/day, adults – min. 0,0086 mg/kg/day and max. 0,27 mg/kg/day. Wholly, a child inhales mean 0,11 mg/kg/day, adult – 0.06 mg/kg/day.

According the map of distribution of dust load (Fig. 3a), the city area is comprised within three pollution zones: high, medium and low (Fig. 3a). High and medium levels of dust load are detected in the west and in the central part of the city and mainly cover

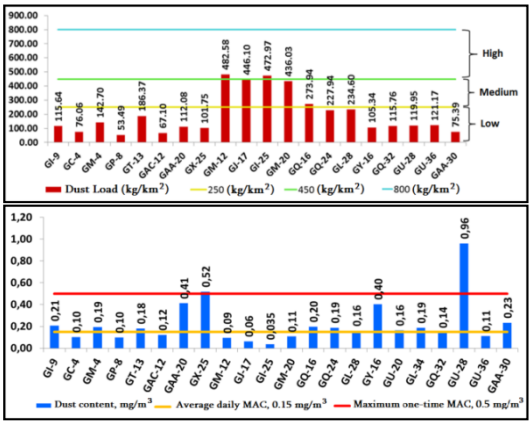

Fig 2. Levels of dust load, kg/km² (upper). Dust content, mg/m³ and comparison with MACs RA (down).

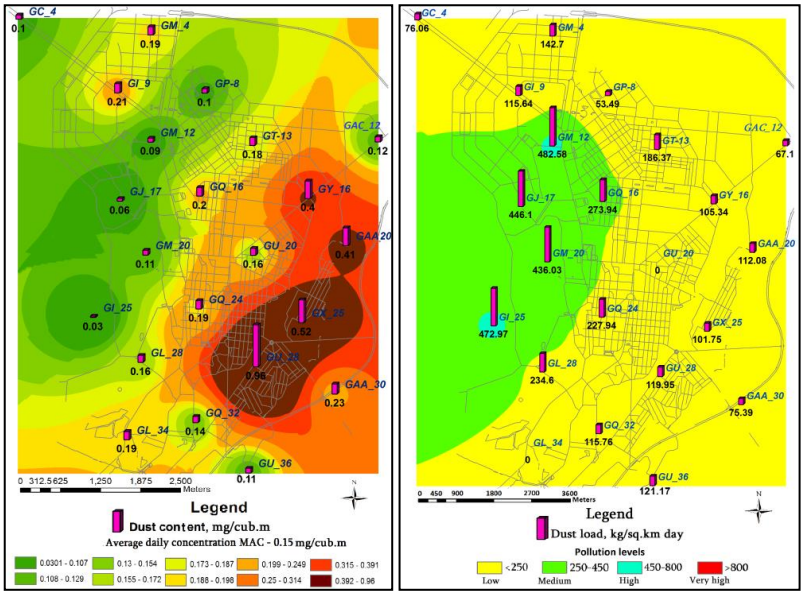

Fig. 3. Maps of dust load (left) and dust content in Gyumri (right).

highways and bare areas where commonly no dwelling houses are found. The map shows (Fig. 3) that unlike dust load, excessive dust contents are common almost to the entire area of the city (Fig. 3b), though major excesses against MAC and peaks of excesses in particular are detected in districts located in the east to southeast which cover both areas alongside the highways and those located amid dwelling houses. Such distribution of dust contents means that dust does not deposit on the bulk area of the city, fine fractions stay suspended in the air. Also, it is noteworthy that in most cases, in northern and southern suburbs (Fig. 3) dust load and dust contents are low; the latter do not exceed MAC, which means that due to natural and man-induces conditions, after entering the city, dust remains in the main part of the city and therefore becomes an environmental and health risk factor for local people. Similar contents of dust are most hazardous to a child who - as compared with their body weight - inhales larger quantities of dust that adults.

It should be noted, that for comprehensive environmental and health risk assessment of dust pollution is needed to investigate chemical composition, asbestos content and PM size of dust and to create a scientifically based monitoring network.

4. Conclusions

The obtained research results allow to conclude that:

- According to the level of leaf dust load, the city area comprises 3 pollution zones: high, medium and low levels of pollutions. Mean daily dust load was 198.35 kg/km^2 that corresponds to low level of pollution. The major part of samples 70% exhibited low level of dust load, some 15% of samples–a medium level (273.9 - 446.1 kg/km^2 with daily variations), 10% of samples –a high level of dust load (473 - 482.6 kg/km^2 with daily variations). Dust load is relatively heavy in the northwest to west and central parts of the city.

- Mean dust content in atmospheric air is 0.22 m^3, which exceeds mean daily MAC by 1,5 times but does not overstep the maximal one-time MAC. In 60% of samples dust contents exceeded mean daily MAC and in 9,5% - the maximal one-time MAC. The highest contents of dust were detected in the east to south- east districts of the city. Major excesses were detected both along principal highways and in the vicinity of dwelling houses.
- On the average, child inhale 0.11 mg/kg and adults - 0.06 mg/kg of dust daily.
- There exists a significant negative correlation (-0,513) of logarithmically transformed values of dust load and dust content, which was proved also by spatial distribution of dust load and dust content.
- Dust is one of dominant pollutants of Gyumri air basin and an environmental risk factor to the local population which need to be investigated and monitored in a more detailed way.

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