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Исследование и анализ основных источников загрязнения Улан-Батора современными физическими методами[1]

Работа посвящена исследованию загрязнения воздуха Улан-Батора и источников этого загрязнения. Среди основных причин – географическое расположение города, естественные и климатические особенности, ошибки в градостроительстве, также загрязнение обусловлено и экономическими причинами. В холодный сезон циркуляция воздушных потоков приводит к обратной температурной инверсии; в результате этого возникает дополнительное загрязнение, обусловленное диффузией частиц в воздухе. Другие факторы связаны с недостаточным озеленением как города, так и его окрестностей, плохим развитием городской инфраструктуры, использованием некачественных нефтепродуктов и др. В Улан-Баторе среднегодовые концентрации твёрдых примесей в атмосфере (PM10) были зарегистрированы на уровне 279 единиц, в то время как рекомендованный Всемирной организацией здравоохранения уровень PM10 равняется 20.

Ключевые слова: загрязнение, источники, жизнедеятельность, анализ

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Investigation and Analysis of the Main Sources of Ulan Bator Pollution by Modern Physical Methods

The paper is devoted to the investigation of Ulan Bator air pollution and the sources of this pollution. The main reasons are geographical location of the city, unique natural and climatic characteristics, and mistakes in town building. Pollution is also caused by economic reasons. During the cold season, air circulation decreases leading to an inverse temperature occurrence and, as a result of this inversion, the polluting waste particles scatter in the air.

[1]Работа выполнена при частичной поддержке РФФИ (грант 12-08-92201) и гранта Министерства образования и науки Монголии

Other factors contributing to Ulan Bator air pollution include destruction of vegetation in Ulan Bator suburbs, lack of green areas in the city, bad infrastructure development, bad quality of oil products, etc. In Ulan Bator, annual average particulate matter concentrations (PM10, i. e. particles that cause damage in the lungs when inhaled) have been recorded at as high as 279. The World Health Organization's recommended PM10 level is 20.

Keywords: pollution, sources, activity, analysis.

1. Introduction

The capital city of Mongolia is Ulaanbaatar. It locates in Central Asia, lies at 1,500 meters above sea level and occupies 470.4 thousand hectares of land. Ulaanbaatar city has an extremely continental climate, including four seasons, and it is one of the coldest national capitals in the world. Winter is cold with an average temperature of $-26\ ^\circ C$ in January. In summer, the warmest month is July with an average temperature of $+17\ ^\circ C$. The highest temperature in July reaches up to $+39\ ^\circ C$, and the lowest temperature in January ranges to $-40\ ^\circ C$. According to the past decades reports, there have been 56 days registered a year with an average daily temperature of $-25\ ^\circ C$ and 55 days with an average temperature of $+15\ ^\circ C$.

According to the 2012statistics, the population of Ulaanbaatar city is reached 1250 000 people, constituting 45 % of the total population of Mongolia. Although the population carrying capacity of Ulaanbaatar is about 400,000. The population density in Ulaanbaatar is 273 people's per square kilometers, which is 160 times more than the national average. In the past 20 years, the Ulaanbaatar's population increased by over 600 thousand including around 80 % mechanical increase of people migrated from rural areas.

This sharp mechanical growth of the Ulaanbaatar population produces many problems in town planning, land use, housing supply and environmental protection. Ulaanbaatar's socio-economic development, its rapid population growth and demographic changes negatively influence the city's environment and produce many different challenges like air, soil and water pollution, degradation and decrease in natural resources.

2. Pollution of air in Ulaanbaatar: main factors, sources and other issues

First of all let's consider a pollution of the air and sources of this pollution. These include among many others the geographical location of the city, the unique natural and climatic characteristics, mistakes of town building, and the country'seconomico-social potential.

Ulaanbaatar is located along the valley of the Tuul River surrounded by four mountain sand therefore, in a cold season the air circulation decreases leading to an inverse temperature occurrence and as a result of inversion the polluting waste particles scatter in the air and the cleaning process slows down. The recent mechanical growth of the

Ulaanbaatar population leads to mismanagement of town planning and expansion of people from rural districts which use the most backward stoves to burn great amounts of raw coal and other flammable, produce smoke and gas wastes in great amount/ special in a winter time. Other factors contributing to the Ulaanbaatar air pollution include destruction of vegetation in the near Ulaanbaatar area (increasing number of livestock near Ulaanbaatar, increasing number of fires), soil erosion and rupture, lack of green areas in the city, use of outdated and old cars (increasing import of old and used cars), bad infrastructure development including roads and bridges (increased traffic jams) and the bad quality oil products, combustibles and lubricants (use of lead containing fuel which is prohibited in most countries).

A counting of air pollution sources of Ulaanbaatar was conducted in 2007. There were counted 1378 small and medium sized low pressure stoves, 128100 ordinary stones owned by private residents, businesses and organizations, three thermal electric power stations and over 150 thousand vehicles in nine districts of Ulaanbaatar. Every year thermal electric power plants burn 3.36 million tons of coal, small sized heating stoves burn over one million tons of coal, households, business enterprises and organizations burn 1.54 million tons of coal and 237195.8 cubic meters of firewood and thus contribute to the air pollution. In addition there are 19 brick factories, 32 gravel factories, 76 hide and leather processing factories, more than 400 car maintenance places (including tire repair, lubricant and spare parts selling points), 4 asphalt factories and over 180 gas stations and petroleum storages in Ulaanbaatar.

In Ulaanbaatar, annual average particulate matter concentrations (PM10, i. e., particles that cause damage in the lungs when inhaled) have been recorded at as high as 279. But the World Health Organization's recommended PM10 level is 20.The source for ***sulfur dioxide*** is burning coal containing sulfur. Each year Ulaanbaatar city burns around 6.0 million tons of coal that is mined from Baganuur and Shivee Ovoo that contain 0.5–0.53 % of sulfur. The sulfur dioxide pollution starts in October and ends in March of each year. Such unpleasant condition happens due to an inverse temperature occurrence and windless cold winters. In months of December and January average daily content of sulfur dioxide is 3–10 times more than the tolerated level of sulfur dioxide. Sources for ***nitrogen dioxide*** pollution are cars that run on high temperature burning fuel, power plants and industrial waste smoke. The nitrogen dioxide level was detected highest in central parts and west 4 road (UB-2); 2–3 times more than the rest of the city parts. According to the air quality control standards, the overall observation in the 2006 demonstrated a 30.6 % more nitrogen dioxide above the tolerated level in Ulaanbaatar city. Sources of ***dust*** content in the air are incomplete combustion products, soil erosion and industrial activities. It can be easily observed during cold seasons, spring storms and winds and in certain parts of the city dust particles rising in the air and polluting the air. According to the study of the Nuclear Research Center, National University of Mongolia, 50 % of Ulaanbaatar's dust in the air derives from soil/eartherosion, and 35 % derives from burning of coal.

Ulaanbaatar city uses coals mined from Baganuur, Shivee-Ovoo and Nalaikh regions and extracted coals contain beryllium, boron, fluorine, thorium, silica, vanadium, chromium, manganese, cobalt, nickel, copper, aluminum, mercury, lead and uranium toxic compounds. Due to lack of experimental and controlling equipment and tools it is not possible to measure the toxic secretions from transportation and industrial processed toxic secretions.

3. Soil pollution is another pressing issue of Ulaanbaatar

In recent years, due to rapid population growth Ulaanbaatar city has also seen a rapid growth in economy, industry, services and infrastructure. Therefore, city's ecology is under a severe degradation due to increase in solid garbage and air pollution which is resulting in severe soil erosion and soil crust pollution. Sources for soil crust pollution and soil erosion are toxic substances in air, smoke and ashes and solid and damp garbage on the ground. Weather conditions and human activities are two main factors that the condition of soil and soil crust depend on.

Weather condition factors: Ulaanbaatar city is surrounded by mountains from all sides situating along the river valley, such condition allows for toxic substances that pollute the soil to move to low depression or to the center of the city and allows them to accumulate together. Along Selbe, Tolgoit and Bayan river valleys in northern part of Ulaanbaatar city mostly gher districts are situated and gherdistrict's smoke and ashes, solid garbage and sewage water absorbed in the soil has a tendency to move towards low depression or to the center of the city creating carrying pollution towards Tuul River.

Climate factor: In the past 60 years Ulaanbaatar city's average atmosphere temperature had risen by 2.0 Celsius degrees which is 1.8 Celsius degrees more than the national average temperature which is due to rapid urbanization and air pollution. The rise in the temperature there is a tendency for ground to solidify and dry as well.

Surface water: Selbe and Tuul rivers are experiencing a low flow and passing time that contributes to the hardening and drying out of river plains. The meadows and marsh soil around the spring source of Selbe and Tolgoit rivers have dried out, as well as melting of the frozen crustallowing for the ground soil to subside and sink. Municipal solid garbage: Each year Ulaanbaatar city generates 260–280 thousand solid garbage of which only 40–50 % is transported out and the rest of the garbage is accumulated around gher districts areas, ditches and gullies thus creating ground and water pollution as shown on picture below.

Industrial waste: In recent years, Ulaanbaatar city has experienced an increase of raw skin processing factories which unfortunately resulted in unsafe and unregulated dumping of toxic polluting waste like 6 valence chromium and dumping of soiled water back into the city's clean water concentration of such factories.

Soil pollution level of Ulaanbaatar city: The soil erosion is increasing in recent years in Ulaanbaatar city. According to the research done from 2003 through 2007 the heavy metal contamination level in soil is lower than the permitted level, but there is a tendency to increase around Tuul River plains in recent years. As shows recent report, the average lead contamination in Ulaanbaatar soil is 45.7 mg/kg that is two times larger than the average uncontaminated and world soil index. In some places the lead contamination has reached 533 mg/kg which is 5.3 times more than the permitted level of contamination. Also, city's soil chromium amount reaching 89.4 mg/kg is another high indicator of contamination. Heavy metals such as Zinc, Cadmium, Copper and Nickel contamination level also are high compared to the average soil contamination of Tuul River basin. Looking at years of dynamic indexes, in 1995 the average level of lead in soil reached 30 mg/kg, in 1999 it reached 36 mg/kg and in 2006 the level reached 45.7

mg/kg indicating a rapid growth in soil lead contamination in Ulaanbaatar city soil. The primary source for soil lead contamination is leaded petroleum used in transportations.

4. Pollution by heavy metals: sources and analysis of concentration

One of strong but ignore anthropogenic source of air and soil pollution with harmful heavy metals like as lead, cadmium, chromium, selenium, and arsenicarepaints that are widely used in Ulaanbaatar to paint buildings, indoor walls, floors and furnitures.

To understand the situation the heavy metal contaminants such as lead (Pb), cadmium (Cd), chromium (Cr), selenium (Se), arsenic (As) were analyzed and determined in samples of oil and ochre paints belonging to best selling brands in Ulaanbaatar city market places. Imported from China red, yellow, green, and blue color oil paints of Honglian,Chulei, and Shunshiyouqi brands (12 samples), 8 samples of ochre paint (Chinese origin, but exact names of producers are unclear), 3 samples oil paints of Russian brand name «Ленинградские краски» were selected for analyses. Also were analyzed scraped samples of yellow and blue oil paint layers from wall of main building of the NUM. Images of tested samples are shown on the Fig. 1.

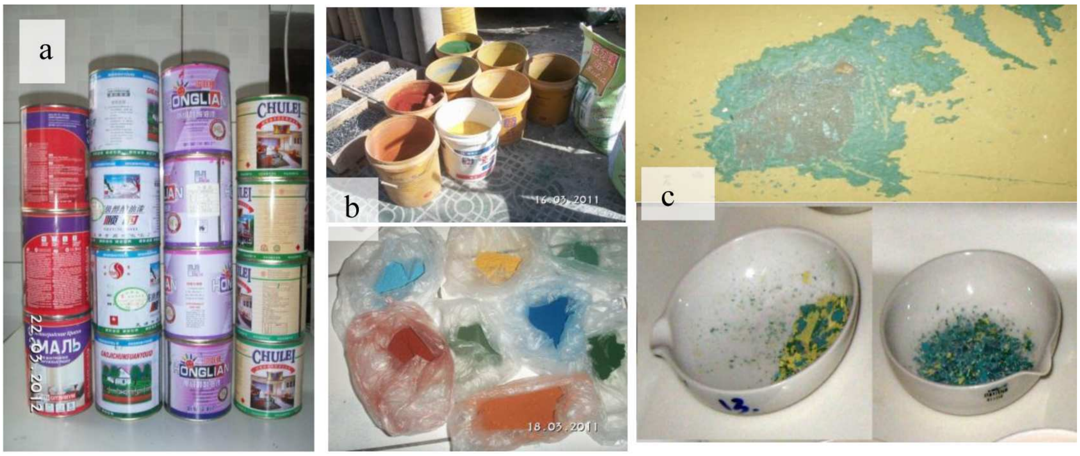

Figure 1. The selected samples of oil paints (a), ochre paints (b), and scraped from wall of the NUM oil paints (c)

For the X-ray diffraction analyses, weighted samples of oil paints were dried 48 hour at 2000C in drying cabinet T6200 (Heraeus) and then ashed 6 hours at 6000C in muffle furnace K1253F(Heraeus). Ochre paint samples were not ashed. For the atomic absorption analyses, dried and accurately weighted samples were digested in suitable acid mixture of HCl, HNO3, HClO4, H2O2 using microwave digesting machine MLS1200 (Milestone) which was differently programmed for each type of sample. Reference solutions (Merck) for the atomic absorption measurements were 0.05, 0.1, 0.2, 0.5, 1.0, 2.0 ppm for all five elements Cd, Se, As, Cr, and Pb. Right before atomic absorption measurements, the digested samples were diluted with blank solution in ratio from 1:1 to 1:100, because of high concentration of desired elements in digested samples. Atomic absorption measurements were done on Solaar5M (Thermo Elemental) spectrometer using default setting of the spectrometers own software [3]. Sample preparation and measuring procedures were commonly used ones [4], so we hope that total relative error of our determinations were not exceeding 15 %.

Concentrations of elements Cd, Se, As, Cr, andPbdetermined by atomic absorption method are shown in the table below. Concentrations are given in milligrams per a kilogram of initial weight of sample (wet weight of oil paint and dry weight of ochre paint).

As seen from the table, cadmium content in samples 16 and 17 (paint scraps from the wall of the NUM main building) are respectively 20 and 12 mg/kg and in other paint samples cadmium is not exceeding 2 mg/kg. Cadmium and compounds of cadmium are classified as B1 group human carcinogens [3]. The US Environmental Protection Agency (EPA) is estimates tolerable concentration (TC) of cadmium in air as $0.06\mu g/m^3$ for an inhalation exposure, and TC for a dietary exposure 0.001mg/kg/day (0.001 mg per a kg of body weight, per a day) [5]. Much higher than TC content of cadmium in paint scraps of the NUM building might create high level of cadmium inhalation exposure to all indoor workers, and specially to workers who will scrap these old layers of paint during repairing works.

Sample number	Sample name	Element concentration, mg/kg (ppm)				
		Cd	Pb	Se	Cr	As
1	Honglian Red	1.1	314	50	68	0.0
2	HonglianYellow	1.1	13240	30	2170	0.0
3	Honglian, Blue	1.1	13.3	65	47	16
4	Honglian, Green	0.0	4760	0.0	1175	37
5	Chulei, Yellow	1.0	25480	26	2334	74
6	Chulei, Blue	1.1	5.8	38	16	7.2
7	Chulei, Green	1.1	0.2	51	2.9	29
8	Chulei, Red	1.4	3571	88	93	57
9	Shunshiyouqi, Yellow	1.2	8826	28	1873	54
10	Shunshiyouqi, Red	2.0	985	27	249	43
11	Shunshiyouqi, Blue	2.0	35	27	3.4	111
12	Shunshiyouqi, Green	1.8	6752	50	1657	0.0
13	Ленинградские краски,Red	1.2	1251	20	2.5	32
14	Ленинградские краски,Green	1.5	838	1.0	3.5	35
15	Ленинградские краски,Blue	1.7	1086	0.0	3.0	9.3
16	NUM wall paint sample, Blue	20	238	26	365	82
17	NUM wall paint sample, Yellow	12	1979	46	1277	110
18	Ochre_Green_1	0.2	65	9	64	28
19	Ochre_Green _2	0.3	151	23	33	26
20	Ochre_Green_3	1.3	102	23	169	36
21	Ochre_Dark Blue	<0.05	8.9	20	13	35
22	Ochre_Light Blue	0.4	16	63	21	23
23	Ochre_Yellow	0.2	9086	56	2820	33
24	Ochre_Yellowish Red	2.1	2997	214	79	743
25	Ochre_Brownish Red	<0.05	723	172	218	18

Lead content in the yellow and red color Chinese paints are high as 300–25000 mg/kg and low as below 40 mg/kg in the blue color paints. It is well known a health hazards of a lead and lead based paints [6], so the US Consumer Product Safety Commission (CPSC) is banned lead containing paints for any indoor use since 1978. Therefore the investigated red and yellow color paints may be used only for outdoor works. As shown the paint ash X- ray diffraction measurements, crystal structure of lead compounds in these paints are oxidized carbonates of lead Pb3CO5*2PbOand PbCO3*2PbO. We suppose that the part of initial lead carbonates were oxidized during high temperature ashing of samples in furnace. As shows in the table, selenium content in oil paints not exceeds 90 mg/kg and reaches 214 and 176 mg/kg in the yellowish and brownish red color ochre paints (sample 24 and 25). Selenium is not toxic, but long term inhalation-ingestion exposure higher than 0.4 mg/day will be harmful [7]. Therefore construction workers, sellers of ochre paint powders must work wearing a safety mask to avoid inhalation of ochre paint dust.

Chromium is detected in yellow and green color oil paints and yellow color ochre paints (samples 2, 4, 5, 9, 12, 23) as much as 1175–2820 mg/kg. Sixvalentchromium(Cr^{6+}) is well known human carcinogen. In accordance with the EPA standard, chromium tolerable exposure per a day for an adult male is $35\mu g/day$, for an adult female is $25\mu g/day$ [8]. According to the EPA, chromium content in drinking water must be below 0.1 mg/l [9] and in accordance with the US Occupational Safety and Health Administration (OSHA) chromium in dust air must be below $5\mu g/m^3$ [10]. Painting floors with yellow color oil paint is wide spread practice in Mongolia. As shows numbers in table above, due to this practice, indoor air may be constantly contaminated with chromium and lead. For example, a classroom floors in ordinary high schools in Mongolia are repainted each year during summer vacation time. If suppose 1 kg oil paint spending each summer for repainting of floor of classroom, a paint chips that scraps from the floor and spreads in classroom air as a microscopic dust particles will be also 1kg during one academic year. It will contain 1.28–2.82 g of chromium, and if suppose 180 days per an academic year, the floor of classroom will produce per a day moveable with dust chromium amount 200–450 times as the EPA per a day standard for adult male.

While the oil paint samples contain arsenic up to 111 mg/kg (33.6 mg/kg averagely), arsenic content in yellowish red ochre paint (sample 24) soars to very high content of 740mg/kg. Arsenic is a high toxic poison and classified as a group A human carcinogen, so the EPA is defined arsenic tolerable daily level goal as zero [11]. But completely removing arsenic from all human habitation environments is still impossible. So the EPA currently established arsenic TC in drinking water low as $10\mu g/l$, TC in air as

$2\mu g/m^3$.

The discovered high level of arsenic content in paints is very concerning fact. In these circumstances, a reduced use of certain Chinese origin yellow and red oil and ochre paints for indoor design works will be reduce contaminant level of arsenic and also other heavy metals as lead, chromium, and cadmium. It will significantly reduce a number of adverse health effect cases caused by presence of these elements in every day environment.

6. Impact of pollution and inspection of pollution

The most serious negative impact due to air pollution is a negative impact on public health. Not only human beings but also plants, animals, as well as environmental degradation and constructions and buildings may receive certain damages due to air pollution. According to the research data, due to growing air pollution, during winter months the spread of respiratory diseases has been increasing especially among children; it has been validated that 93.77 % cases of diseases cause from the air polluting substances. For instance, air pollution is the 90.91 % cause for children's bronchitis. Reconnoitering research based on pediatric hospital has proved that in sources of overall diseases 38.3 % was accounted for air dust source, and overall polluting substance based diseases accounted for 43.14 %. Researchers have suggested that the increased allergic based diseases and cancer causes could be linked to the air pollution as well. Due to the lack of sufficient research on public health and air pollution correlation there has not been given an adequate conclusion on this matter.

There are four permanent watch posts in Ulaanbaatar city where air quality is tested, monitored and measured regularly by checking the daily average content of sulfur dioxide and nitrogen dioxide in the air. UB-1 watch post is located at Khan-Uuldistrict's 3d khoroo's industrial district, UB-2 watch post is located at nearby Bayangoldistrict?s West 4 road, UB-3 watch post is located at Songinokhairhandistrict's Bayankhoshuu and UB-4 watch post is located at Bayanzurkhdistrict's 13thmicro district. According to world standard the watch posts are situated and installed according to the population density, geographical location and size in order to produce precise and quality data. For instance, Japan installs watch posts per 75 thousand people, and if followed such example Ulaanbaatar city should have 14 watch posts installed that will allow to control and monitor air pollution effectively.

7. Conclusions and recommendations

High level of concentration 300–25000 mg/kg for lead, 1280-2820 mg/kg for chromium,up to 74 mg/kg for arsenic are detected in all samples of yellow and red color oil paints of 3 selected Chine's origin brands. Alarming high concentration of arsenic -740 mg/kg – is detected in yellowish red color ochre paint.

As shows our AAS analyses results, the yellow and red color Chinese paints of above mentioned brand names might be hazardous and even dangerous if they will be used to paint interior of public and residential house buildings which will create potentially contaminated indoor environment to human.

The discovered high level of lead, chromium, and arsenic content in paints is concerning fact. A use of certain Chinese origin yellow and red oil and ochre paints for indoor design works must be reduced significantly or if possible, must be banned at all.

Future research must be focused on much more extensive and detailed investigation of lead, chromium, and arsenic in all paint brand names available on Mongolian market. Results of such research may become essential guide document for government import licensing-banning legal authority, for importers in choosing of proper paint brands to be imported into country.

For more detailed analysis of pollution it is necessary to study too mechanisms of diffusion of particles with using the fractal approach and method of fractional order derivatives [12–15].

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