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Lead analysis of air pollution in Istanbul utilizing by the vehicle cabin air filters

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Abstract

Objective: Lead that are common in nature and widely consumed through industry and transportation are leading metals that cause toxicity in humans and other living organisms. The cabin air filters are made out of paper with many layers having the ability to capture particles with nearly one micron size or higher. Aim of this study is to search the trace element pollution in the air, in different regions by analyzing lead concentration in cabin filters of 10 different vehicle marks, obtained from various auto services in the city of Istanbul-Turkey.

Methods: All collected filters were initially resolved in the HCl and HNO_3 mixture. Lead levels that had been adsorbed in filters were measured by Atomic Absorption Spectrophotometer (AAS). Results of the study were further analyzed by region where the sample air filters were originally collected.

Results: According to our findings, it has been observed that lead levels in 5th region are maximum compared to the other regions of Istanbul-Turkey.

Conclusion: This fact concludes that the used vehicle cabin air filters are one of the best sources to get information about air quality and pollution levels. The results of this research exemplifies and concludes that utilizing replaced cabin filters is an efficient and effective method to measure heavy metals pollution in big cities such as Istanbul, Turkey.

Keywords: Heavy Metals, cabin air filters, Lead (Pb), air pollution Istanbul-Turkey

Introduction

Nearly 70 metals including lead, aluminium, chromium, tin, cadmium, titanium and strontium, called as heavy metals because of their high densities, are taken into body through air, water and food. Lead (Pb) and cadmium (Cd) that are common in nature and widely consumed through industry and transportation are leading metals that cause in toxicity in humans and other living organisms. Pb exposure is by means of respiratory and digestive systems and skin. Pb is mostly cumulated in bone tissue, liver and kidneys. It is a toxic element that gets through blood-brain barrier [1, 2, 3]. Pb is found in solid (dust and usually PbO_2 particles) and gas (Alkyl Pb, released from exhaust gases) phases in atmosphere [4]. Dust that is formed during industrial grinding and leaded fuels are the most important resources of Pb in air. It's very small particular structure enables it to reach alveolar surface without being attached to barriers in nasal and respiratory tracts. Nearly 90% of Pb in atmosphere is emitted by lungs, and more than 90% of emitted Pb is collected in erythrocytes. By time, since alveolar surfaces are as much permeable to toxic materials as it is to oxygen; this causes a risk of toxication. It is stated that there is linear relation between Pb concentration in air and Pb concentration in blood [5]. Goodman and Gilman [6] studied that consumption of 2.5 mg Pb per day will in 4 years, and 3.5 mg Pb per day will in months result in Pb toxication. Usually when Pb concentration in air is about 0,001 mg/m^3, Pb level in blood will increase to 0,01-0,02 µg/ml [7]. Pb, even in a very small amount is absorbed from gastrointestinal system and transmitted to tissues by blood. Inorganic Pb compounds are absorbed from adult gastrointestinal system by 10% or less. There are a lot of factors effecting Pb absorption in gastrointestinal system, such as existence of calcium, phosphorus, iron, zinc and copper; age and the physical condition of the person [8]. On the other hand, it is reported that deficiency of iron, zinc and calcium redoubles Pb absorption in gastrointestinal system [9; 10]. Matousek and Brodie [11] have analyzed the Pb amount that is absorbed both from the respiratory tract and the gastrointestinal system, and they observed that lead taken through respiratory system is 5 times more than the amount absorbed from the gastrointestinal system. Pb is also stored in soft tissues and its half-life is approximately 2 months.

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Brain is an exception; Pb gets through blood-brain barrier slowly, and its biological half-life is more than one year. Besides, it results in astrocyte accumulation and affects the glutamate balance [10, 12]. Some of the lead is disposed by the gastrointestinal system via faeces but main excretion is from the urinary system (76%). Also it is excreted from the organism by hair, nails and perspiration in small amounts [7].

According to World Health Organization (WHO)'s classification, Pb is a 2nd class carcinogenic [13]. Contagion through soil and dust carries an important role in toxication, too. Because tetraethyl and tetra methyl compounds of Pb are used as fuel additives, they have importance in air and environmental pollution. Pb compounds that are formed with the burning down of fuel are diffused in atmosphere, turning into oxide, chloride, sulphate and phosphate compounds of Pb [11, 14, 15]. It is stated that Pb pollution in air varies depending on the number of motor vehicles in different countries. In our country, allowed Pb amount in fuel was 0.80 g/l in 1988, decreased to 0.21 g/l in 1998 and 0.13 g/l in 2009; and was decided to be Pb -free in 2012 [16]. Though Pb concentration in air has a downward trend since Pb free fuel consumption is improving, still Pb pollution is a serious environmental risk factor for especially children and pregnant women [1, 17]. Determination of Pb amount in blood and tissue is the most valid method in Pb toxicity analysis [12, 18]. Decrease in blood Pb concentration (B-Pb) is observed with the start of Pb free fuel consumption [9, 15, 19].

Number of vehicles per person in our country is increasing rapidly especially in big cities like Istanbul, Ankara, Izmir, Adana etc. It is reported that there are 200 vehicles per 1000 people in Istanbul-Turkiye. In USA, this rate is 700 vehicles/1000 people and 600 vehicles/1000 people in West Europe. Accretion in emission of air pollutants such as carbon monoxide, particles, hydrocarbon and nitrogen resulting from increase in fuel consumption and traffic density is observed connected in parallel with the number of vehicles [20]. Vehicles that are not being examined, repaired and controlled for their exhausts periodically, cause more air pollution; especially high amount of sulphur in diesel fuels corrodes the engine, cast of more pollutants from the exhaust and increase of sulphate particles in atmosphere. It is reported that pollutants from vehicles result in health and environmental problems as well as global warming. It is known that the air we breathe is being polluted by the increasing number of vehicles and the use of fossil fuels. Pb that has a part in this pollution is important hazards for human health and different clinical symptoms occur in living organisms that are exposed to these elements [21].

Vehicle cabin air filters are filters that work as regulators of air conditioning systems in our cars. These changeable filters are made of many layers of papers are able to capture particles of nearly one micron size. Since filter materials and their media are very dense, they may create serious resistance in air flow. As the air flow resistance increases, the performance of the filter starts decreasing. . It is stated that paper fibres in vehicle cabin air filters are produced with pores that are big enough to let air ventilation and small enough to capture the dust particles that are not welcome in order to enable effective filtration.. Vehicle cabin air filters have an important design restriction. Moisture and vapour will result in filter element to swell and dilate thus large dust particles will settle in pores, blocking air ventilation. It is again confirmed that blockage of filters increase in dusty places, too. Paper used in the production of vehicle cabin air filters is generally named non-woven; and is produced as a homogenous mixture of materials such as resin, fibre and polyester either woven straight or across. This paper is used in production of vehicle cabin air filters and each different type has specific characteristics such as air permeability, number of pores, tear point, resistance etc. These characteristics play the main role in the lifetime of vehicle cabin filters. The most important thing is the quality of the materials used in the filter. The role of vehicle cabin filters is to filter dust, soot, bacteria and pollens as well as to hinder the entrance of trace elements with the air that gets in [22, 23, 24, 25, 26].

There are two different cabin air filters. One of them is standard the other is active carbon air filter. Active carbon air filters have active carbon layer that absorb particles in gas form like ozone, benzol and toluel and thus disabling these harmful elements to reach inside the cabin. It is observed that the particles adsorbed by active carbon cabin filters are in micron (μ) size (Figure 1) [23, 25].

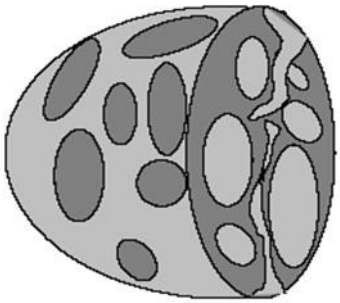

Figure 1. Schematic representation of the pore structure of active carbon particles [27]

Activated carbon is one of the best tools which can be used to reduce risks to human health. Activated carbon adsorption proceeds through 3 basic steps;

Substances

1. Adsorb to the exterior of the carbon granules
2. Move into the carbon pores
3. Adsorb to the interior walls of the carbon

The most important difference of active carbon cabin filter from the standard filter is that it can adsorb the unwanted scent without letting the poisonous gases (ozone, benzol and toluel) leak inside the cabin. Paper characteristics of the active carbon cabin filter is; one layer with the same features with the standard filter paper that has double filter effect and the other layer absorbing coal dust (Figure 2) [20, 28].

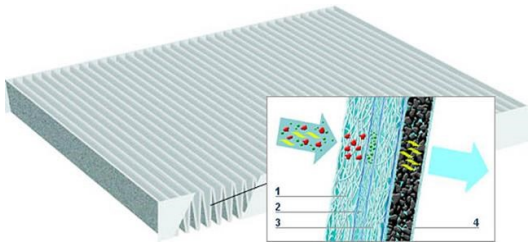

Figure 2: Schematic illustration of active carbon cabin filter [20]

The reason that activated carbon is such an effective adsorbent material is due to its large number of cavernous pores. These provide a large surface area relative to the size of the actual carbon particle and its visible exterior surface. An approximate ratio is 1 gram = 100 m^2 of surface area [22, 24].

Material and Methods

Materials

In our study, vehicle cabin air filters of various standard vehicle marks that had been obtained from different car services from several regions of Istanbul had been used. Air pollution was analyzed in 7 different regions by the help of cabin air filters taken from different car services (Figure 3).

Regions Specifications

It is reported that Istanbul takes the first place in all cities of Turkey according to the licensed vehicles traffic density with 34% among other cities according to the data dated in November, 2010 (Table 1) [30]. In European part of Istanbul-Turkiye, other regions considered as blind spots because of their heavy traffic are as follows in decreasing order: Avcılar (6^{th} region), Bagcılar (5^{th} region), Bahcelievler, Bakırkoy (4^{th} region), Besiktas (7^{th} region), Eyup (1^{st} region), Gaziosmanpasa (2^{nd} region), Gungoren (5^{th} region) and Zeytinburnu (4^{th} region) (Figure 3) [26].

Experimental Design

Vehicle cabin air filters of cars at 12.000-15.000 km had been collected from different regions of Istanbul-Turkiye with the allowance of car owners. All filters' weights had been measured on sensitive scales.

Figure 3. Location of seven different regions in Istanbul-Turkey in map scale (795x701 pixel)

Region 1: Eyup- Alibeykoy
Region 2: Bayrampasa-Gaziosmanpasa
Region 3: Zeytinburnu-Eminonu-Yenikapi
Region 4: Bacelievler-Bakirkoy-Atakoy
Region 5: Bagcilar- Gungoren-Mahmutbey
Region 6: Sefakoy- Avcilar- Kucukcekmece- Esenyurt
Region 7: Besiktas- Mecidiyekoy

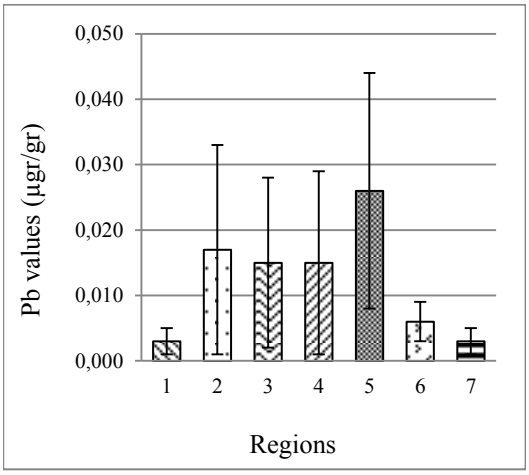

Figure 4. Average values of lead concentrations in cabin air filters of seven regions. Mean±SD, n=8

Materials that had been prepared were grouped in five. Solutions of 3HCL (Rhiedel) + 1HNO_3 (Merck) (gold bath-aquaregia) mixtures of 100 ml were prepared in 200 ml measures, and they were added to filters providing full submerge of filters in solutions. Vehicle cabin air filters were left to dissolve in room temperature, shivering and engaging to solutions with polypropylene bonds in shape of small thread balls. In order to maintain enough diffusion, all experimental filters were left in room temperature for 48 hours; and then different sized particles formed from adsorption of filters dissolving in beakers, were transferred to experimental tubes with lids. After filtration, used and control group cabin air filters were eliminated from the dust particles that have dissolved in solutions by centrifugation [27, 28, 29, 30].

Determination of Lead

Since Atomic Absorption Spectrophotometer (AAS - Shimadzu-AA680) measurement system is a rapid measurement tool for the analysis of air originated particle materials.

Thus samples were completed to 5 ml total volumes with automated pipettes; and the lead levels in dust particles that are adsorbed in cabin filters were measured in AAS device located in I.U. Cerrahpasa Medical Faculty, Biophysics Department [31, 32].

Statistical Methods

Statistical comparison and evaluation to determine the trace element levels belonging to different cabin air filters from 7 specific regions of İstanbul, SPSS (version 17.0) package program have been used. Results were declared as average and standard deviation (M±SD). Data were tested at significance levels of $p < 0.05$ using Mann-Whitney U Test.

Results

Vehicle cabin air filters of several vehicle marks that had been collected from different car services in Istanbul's various regions were separated according to seven different regions and their Pb values were measured. Pb measurements were compared; averages and standard deviations are shown in Table 2.

When the values of Pb in cabin air filter solutions in all regions were compared, Pb values of Region 1 versus Region 5 (0.003 ± 0.002 µgr/gr; 0.026 ± 0.018 µgr/gr) showed a statistical significance ($p<0.001$). Region 5 (0.003 ± 0.002 µgr/gr) versus Region 6 (0.006 ± 0.003 µgr/gr), Pb values also showed a statistical significance ($p<0.001$). The Pb values of Region 5 were measured higher than the other Regions. The values of Pb in cabin air filter solutions, Pb were significantly higher in Region 7 (0.014 ± 0.010 µgr/gr) than Region 1 and Region 6 (0.003 ± 0.002 µgr/gr; 0.006 ± 0.003 µgr/gr) ($p<0.05$, $p<0.01$). Significance was also demonstrated between Region 7 (0.014 ± 0.010 µgr/gr) and Region 5 (0.026 ± 0.018 µgr/gr) at Pb values ($p<0.05$). Furthermore, there was not a difference among Regions 1, 2, 3, 4 in cabin air filter solutions Pb values (Figure 4).

Table 1. The regional effects of population, traffic and industry on trace elements in air pollution

Regions	Population	Traffic	Industry
Region 1	increasing	heavy traffic in weekdays	decreasing
Region 2	crowded	heavy traffic in all days	spare parts, metalwork, moulding, electric-electronics parts production, plastic foundry, cold iron embroidery, machining, hardware production,textile
Region 3	varies during the day	heavy traffic in all days	Leather and weaving industry
Region 4	crowded	heavy traffic in all days	Textile and weaving industry
Region 5	irregular increasing	heavy traffic in all days	Automotive, textile, industrial electronics and metal products industries and factories; as well as all turnery, automat and welding, rubber production (rubber, shoes, steelwork etc)
Region 6	crowded	heavy traffic in all days	Construction sector
Region 7	crowded	heavy traffic in all days	Shopping malls, company head offices, banks, plazas, international hotels and some pharmaceutical companies

Table 2. Values of Lead (Pb) concentrations in cabin air filters of seven regions

Regions (n:8)	Pb values (µgr/gr)
Region 1	0.003 ± 0.002
Region 2	0.017 ± 0.016
Region 3	0.015 ± 0.013
Region 4	0.015 ± 0.014
Region 5	0.026 ± 0.018 ^{a***}
Region 6	0.006 ± 0.003 ^{e***}
Region 7	0.003 ± 0.002 $^{e*, f**}$

Data are Show as the mean ± SD, **a** Statistical comparison Region 1, **b** Statistical comparison Region 2, **c** Statistical comparison Region 3, **d** Statistical comparison Region 4, **e** Statistical comparison Region 5, **f** Statistical comparison Region 6, **g** Statistical comparison Region 7 with other Regions* $p<0,05$, $^{**}p<0,01$, $^{b***}p<0,001$.

Discussion

Every year, approximately 3 million people die because of air pollution. This rate is 5% of all deaths (nearly 55 million) in the world in one year. 90% of deaths resulting from air pollution is observed in developing countries. As a consequence of unwanted effects of air pollution to health; it is observed that there is an increase in lung cancer, chronic asthma chrisis, asthma, frequency in cough/sputum, acute disorder of upper respiratory system, eye/nose/throath damage and health costs; and decrease in business efficiency and production. Particles in air are composed of solid and liquid drops. Some particles are thrown away from chimneys. Some are formed in atmosphere**.** Particles that are smaller than 10 µm are important and they may be transferred to kilometres away with the wind effect. Small particles as (PM_{10} and $PM_{2.5}$) reach to lungs with the respiratory tract and they cause serious health problems. PM_{10} has 5 times and $PM_{2.5}$ has 20 times smaller diameter than human hair and they may only be detected by electron microscope [33].

The main aim of vehicle cabin air filters is to block the entrance of pollens and dust inside the cabin in order to increase the quality of air that is being breathed by driver and passengers. It was observed that the first cabin filters produced were nearly incapable of capturing the particles entering inside the cabin. With different type and structures of filter production, decrease in irritation (eye/nose/throat damage) and in symptoms of allergy to pollens and dust, originating from exposure to heavy metals in air has been observed in drivers and passengers [23]. In the study of Rudell et al [34], it is reported that number and concentration of particles with the size of 0.4 µm or smaller entering inside the cabin varies with the usage of different structured filters. Kalman et al. [35] demonstrated that in order to increase the quality of air inside the cabin, active carbon cabin filters are being used as new technology. Active carbons with developed pores are the most important of adsorbents that are used as industrial adsorbents at the time, to avoid environmental pollution [25]. In our study, active carbon filters belonging to 10 different cars were used. Our aim in this study was to determine trace element pollution in air, by measuring lead concentration in 7 different regions of Istanbul.

The highest levels of Pb measured were in 5th and 2nd regions (Figure 4). Pb levels in these 2 regions being meaningfully high leads to think that lead release to air might be the maximum because of these two regions being industrial zones. Another reason effecting lead level in 5th region might be the increase in construction sector. We confirmed that lead concentration in 7th region is higher than the 6th region. This might be because the traffic density was higher, and the main highway to the Bosphorus Bridge is in 7th region.

WHO (1996) declared that Pb concentration that effects air pollution in big cities worldwide is 0.002-0.004 mg/m^3. It is also known that air pollution varies with the countries' number of vehicles. Kismet et all [16] analyzed in their study that with the start of unleaded fuel, Pb concentration in air has decreased. Considering Pb levels found in our study (Figure 4), the maximum values found in filters were from the 5th region (0.026 ± 0.018 µgr/gr) and the 2nd region (0.017±0.016 µgr/gr). These areas being industrial and having heavy traffic supported the results' accuracy. On the other hand, Sezgin et al. [36] have found out that Pb levels measured in dust samples taken from 22 different points in E-5 highway-routes of regions 4 and 6 in our study- were 9-11 times higher than the normal Pb level in soil. Sezgin et al. [36] demonstrated Pb levels in dust coming from these areas as 211.88 mg/kg (dry soil normal lead level is 20 mg/kg). In our country, it is reported that air pollution in big cities are 40% traffic originating and this problem keeps going on especially in Istanbul-Turkiye. Lead, zinc, copper and iron levels are especially high in areas with huge traffic density and this is being supported by the study, too [37].

Overall, data presented in this study suggest that using vehicle cabin air filters to determine the trace element pollution in air is a very effective and suitable method. According to our findings; most pollution was reported in the fifth region. Bagcilar - Gungoren- Mahmutbey having not only automotive, textiles, electronics and other metal industries but also non-stop traffic through the day contribution to the pollution. In drivers and passengers of regions that have high lead concentrations in air, increase in symptoms of toxication effect (irregularities in respiratory system, eye/nose/throat irritation, crisis of asthma) may be expected.

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