MJFAS MALAYSIAN JOURNAL OF FUNDAMENTAL AND APPLIED SCIENCES
PRINT ISSN: 2289-5981 | ONLINE ISSN: 2289-599X

RESEARCH ARTICLE

Heavy metals in the air: Analysis using Instrument, air pollution and human health - a review

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Article history
Received 9 January 2018
Revised 26 Mac 2018
Accepted 20 May 2018
Published Online 16 December 2018

Abstract

Air pollution can harm human health, cause-effect to the environment and trigger factor to property damage. Various researches have proven the connection between air quality and human health. The previous research on epidemiology and laboratory studies demonstrated that ambient air pollutants (for example PM, O3, SO2 and NO2) contribute to various respiratory problems including bronchitis, emphysema and asthma. This present mini-review is to discuss the relationship between human health and air quality. This conceptual paper is focusing on the findings from air quality based on literature review and the significant health effects which related to it. Besides, the principle of analytical instrumentation is also being discussed in order to identify the best instrument in laboratory analysis.

***Keywords*:** Heavy metal, the principle analysis, human health, toxic, air pollution

INTRODUCTION

Heavy metals are referred to the metals with the density of at least five times higher than water (Adani *et al.*, 2015; Nagajyoti *et al.*, 2010). In the air, heavy metals can accumulate from the sources such as mining process, fossil fuel's combustion, metallurgical process, incineration activities, industrial plants and windblown soil dust (Adani *et al.*, 2015; Hassanien, 2009; Kampa and Castanas, 2008). Researchers all around the world such as in Brazil (Silvia *et al.*, 2004), Denmark (Karl and Liaquat, 2002), Portugal (Vasconcelos and Tavares, 1997), India (Khillare *et al.*, 2004, Spain (Moreno-Grau *et al.*, 1997; Mateu *et al.*, 1999; Moreno-Grau *et al.* 2000), Egypt (Abdel-shary *et al.* 1992), and Russia (Drobyshev and Emelina, 2001) have studied a number of heavy metals. From the findings, several numbers of heavy metals are dangerous and can lead to pollutants in human health and the environment. This will disrupt human's vitality as well.

Heavy metals had a relation with the respirable dust particles. The sizes of heavy metals inside the dust, below than 10 µm can merge deeper in lungs, retained inside the lungs and cannot be moved out easily with exhalation and inhalation process which able to harm the human health (Chaudhari *et al.*, 2012; Srivastava and Majumder, 2008; Hsan, 2008). Heavy metals in environmental dust can enter human's tissues and internal organs. This accumulation processes of heavy metals inside a human body are done through respiration, skin contact, ingestion and absorption (Aelion *et al.*, 2008; Ahmed and Ishiga, 2006; De-Miguel *et al.*, 2007; Sezgin *et al.*, 2003). This process will trigger the effects on human health and vitality (Faiz *et al.*, 2009). The concentration of heavy metals in air showed spatial variation. This process occurred due to air and heavy metal's concentration based on distances to the sources and the relative importance of local sources. The concentration levels of heavy metals in the air are influenced by the speed and direction of the wind and seasonal variations (Gharaibeh *et al.*, 2010).

During outdoor activities, people can easily come into contact with airborne metals. The particulate matters are involved in their food and beverages, inhalation of fine particulates and dermal contact with particulate fallout (Bian *et al.*, 2015).

The analysis for dust in the air was conducted by using the aqua regia method described by Radojevic and Bashkin (2006). Aqua regia method is a process of a mixture of nitric acid and hydrochloric acid. They are optimally in a molar ratio of 1:3. This digestion procedure is considered adequate for environmental samples (Chen and Ma, 2001; Vercoutere *et al.*, 1995). Aqua regia digestion (Soon and Abboud, 1993) is used widen to determine the contents of heavy metal elements in environmental tasks (Taraškevičius *et al.*, 2013).

Instead of aqua regia digestion method, inductively coupled plasma mass spectrometry (ICPMS) is also classified as one of the techniques used for the analysis of heavy metals. This analysis is

considered to be the best technique due to its sensitivity, selectivity, reproducibility, wide dynamic concentration range and its low cost (Thomas, 2008). ICPMS is a powerful technique that allowing the multielemental ultra-trace analysis of a wide variety of samples. The spatial variation of heavy metal concentration can be analysed using the advanced statistical technique, named chemometrics.

DIGESTION AND THE PRINCIPLES OF INSTRUMENTATION

Digestion through aqua regia method

The samples and heavy metal content for air particulate in the certified standard reference materials (NIST®SRM® 1648a) were digested for elemental analysis. The SRM® 1648a standard was used for checking the quality and accuracy of the quantitative analysis. Digestion samples were conducted using the aqua regia method as described by Radojevic and Bashkin (2006). Aqua regia method is a process of a mixture of nitric acid and hydrochloric acid (Azaman *et al.*, 2015), optimally in a molar ratio of 1:3, which is a digestion procedure that considers adequate for environmental samples (Chen and Ma, 2001; Vercoutere *et al.*, 1995). Aqua regia digestion is widely used for the determination of the contents of heavy metal elements to solve environmental tasks (Soon and Abboud, 1993; Taraškevičius *et al.*, 2013).

WhatmanTM filter papers (blank and samples) that have been cut into small pieces and SRM® 1648a were placed into a 100 mL beaker (separate beaker, respectively) and treated with 50 mL of aqua regia. The beakers were covered with watch glass during the heating process. The mixture was heated at 140ºC to near dryness. The samples were filtered off while the beaker rinsed with 10% HNO_3 (Samsudin *et al.* 2017). These processes were repeated for three times. Then, the solutions were cooled at room temperature, transferred into a 100 mL volumetric flask and diluted to volume with 10% HNO_3 for the final solution.

The principle of atomic absorption spectroscopy (AAS)

Atomic Absorption Spectroscopy (AAS) is a technique of measuring quantities of chemical elements. The elements present in environmental samples are measured through absorbed radiation by the chemical element of interest. The atoms absorb ultraviolet or visible light and make transitions to higher energy levels (Fig. 1).

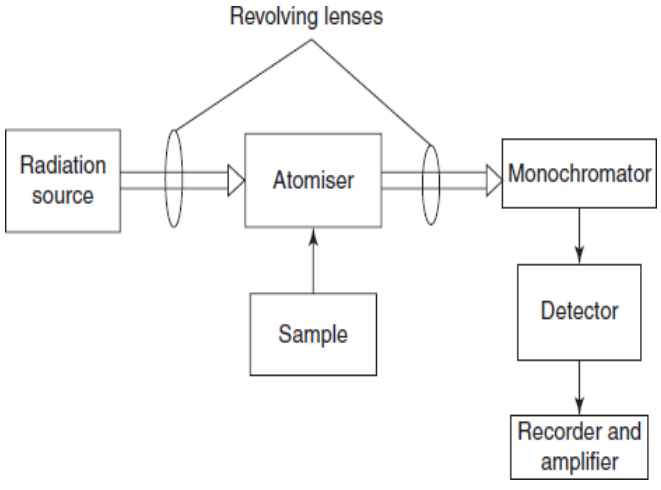

Fig. 1 Atomic absorption Spectroscopy Principle's.

The principle of inductively coupled plasma optical emission spectrometry (ICPOES)

Inductively Coupled Plasma is one method of optical emission spectrometry. The atoms from the component elements are excited when plasma energy is given to an analysis sample from outside. The emission rays that correspond to the photon wavelength are measured when the excited atoms return to low energy position. The emission rays (spectrum rays) are released. Based on the position of the photon rays, the element type is determined. Based on the rays' intensity, the content of each element is determined. In order to generate plasma, an argon gas is supplied to torch coil and high-frequency electric current is applied to the work coil at the tip of the torch tube. After the electromagnetic field created in the torch tube by the high-frequency current, argon gas is ionized and plasma is generated. This plasma has high electron density and temperature (10000K). This energy is used in the excitation-emission of the sample. Solution samples are introduced into the plasma in an atomized state through the narrow tube in the center of the torch tube (Fig. 2).

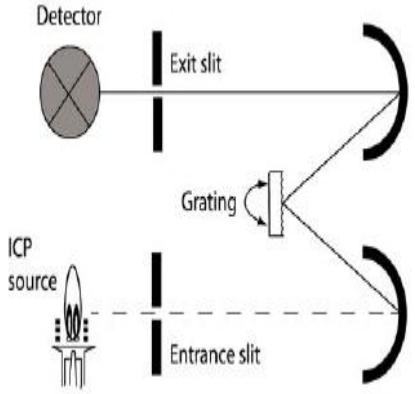

Fig. 2 Inductively coupled plasma optical emission Spectrometry Principle's.

The principle of inductively coupled plasma mass spectrometry (ICPMS)

The ion source, ICP is an ideal ionization source for mass spectrometry and can ionize over 90% of many elements. Ions produced in the ICP are led through the sampling interface to the mass analysis unit. The sampling interface unit consists of two metallic cones, the sampling cone and the skimmer cone and a rotary gear pump ventilates between the two into several hundred Pa condition. The path of the ions pulled through by the sampling cone and the skimmer cone converge into the mass spectrophotometer through the ion lens. The ion lens and the mass spectrophotometer unit are ventilated to 10-3 and 10-4 Pa respectively, by the turbo molecular pump. The ions sorted by mass with the mass spectrophotometer are detected by the ion detector (Fig. 3).

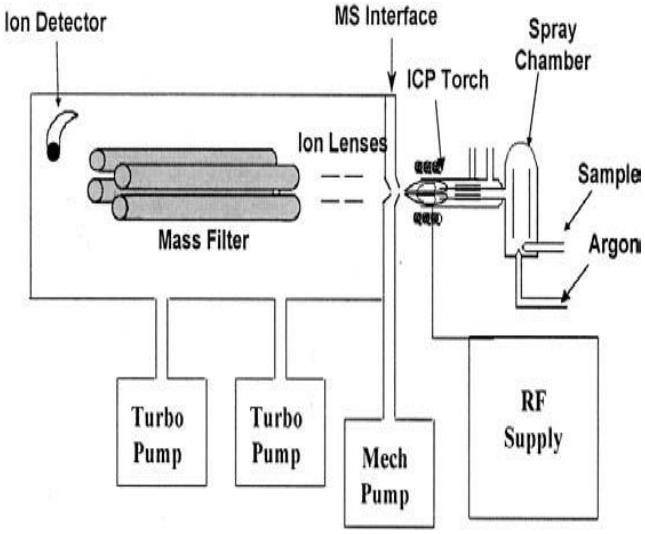

Fig. 3 Inductively coupled plasma mass spectrometry Principle's.

Comparison between analysis by AAS, ICPOES and ICPMS

Based on the above consideration (Table 1), ICPMS gave the best performance in terms of detection limit, the number of elements involved in one time and the amount of sample usage during detection. However, in order to reduce the cost, analysis by using AAS is recommended.

Table 1 Comparison of AAS, ICPOES and ICPMS (Tyler and Jobin Yvon, 1995).

	AAS	ICPOES	ICPMS
Detection limit	Good	Very good	Excellent
No. of elements	>50	>75	>75
Sample usage	High	Low	Low
Skill requirement	Yes	Yes	Yes
Operating cost	Low	High	Very high

HEAVY METALS, AIR POLLUTION AND HUMAN HEALTH

Heavy metals and human health

Heavy metal is divided into two categories, which are essential metals and non-essential metals. Lead (Pb), mercury (Hg) and cadmium (Cd) are categorized as non-essential metals. These heavy metals are clarified as toxic and harmful to organisms, although in a small amount for over a long period of time or in large amount for a short period (Thomas *et al.,* 2009; Zheng *et al.,* 2011). Nickel, copper and manganese are classified as an essential metal. This is due to their important role in the biological process (Fernandes *et al.,* 2008; Stern *et al.,* 2007). The dose-response curve for essential metal is U-shaped. These metals have both effects either deficiency or benefits as well. The excess of copper will produce adverse health (Stern *et al.,* 2007).

Manganese (Mn) is a metal that classified as a metal which involved of low toxicity and effect to organisms. Mn is considered of having biological significance due to their ability to prevent heart attack, stroke and cardiac arrest. Manganese's deficiency will trigger to congenital malformations in the generation of the population, growth retardation and infertility problems in the reproductive system (Saha and Zaman, 2013). However, at high concentrations of Mn, it will become toxic to organisms. This effect may lead to the neurologic and psychologic problem (Saha and Zaman, 2013; Perl and Olanow, 2007).

Iron (Fe) is a mineral essential for every living cell and necessary for the synthesis of myoglobin, haemoglobin and certain process in human's body. Fe's deficiency will result in weakness, susceptibility and inability to concentrate routinely (Akoto *et al.,* 2014). Anderson and Fitzgerald (2010) studied that one of the most common nutrient deficiencies in the world is Fe deficiency in anaemia. Anaemia is a type of disease that gives poor performance in circulatory transport and also will reduce oxygen supply to muscle and brain (Erdman *et al.,* 2012).

Normally, nickel (Ni) is an essential metal and occurs at very low levels in the environment. However, a deficiency of Ni in humans has not been clarified yet (Barceloux and Barceloux, 1999). Ni is known to be carcinogenic for organisms (Salnikow and Kasprzak, 2005). Ni can lead to fibrosis, tumours, lung inflammation and emphysema due to its highly concentrations in the surrounding area (Forti *et al.,* 2011).

Chromium (Cr) is also another one type of essential trace element in certain animals and homo sapiens. This heavy metal may reduce body fat in an adipose tissue and also lead to lean body mass improvement. However, their effects are small as compared to those of having a well-balanced diet and doing proper exercise (Tulasi and Rao, 2014; Roussel *et al.,* 2007). In excess amount, it could lead to fatal effect. Lack of Cr will expose to growth disturbances and reduction in glucose, lipid and protein metabolism (Barceloux and Barceloux, 1999). According to Stipanuk and Caudill (2012), based on meta-analysis, a positive association between Cr and impaired glucose tolerance are recorded.

Zinc (Zn) is a trace element that has a positive impact on humans and plants. Zn is known as a cofactor to enzymes that involved in RNA and DNA metabolism. Zn helps in the structure stabilization in a large number of proteins (Chasapis *et al.,* 2012; Song *et al.,* 2009; Song *et al.,* 2010). Within the large amount, Zn becomes toxic (Krishna *et al.,* 2014). A deficiency of Zn can lead to several disorders (Stipanuk and Caudill, 2012). The problems happen due to Zn's deficiency are poor pregnancy outcomes (Stipanuk and Caudill, 2012; Chasapis *et al.,* 2012) and development of the cardiovascular disorder (Messner *et al.,* 2009; Afridi *et al.,* 2011) and malignant tumour such as cancer (Kazi *et al.,* 2010).

Copper (Cu) is an essential metal of enzymes and necessary for the haemoglobin synthesis (Thomas *et al.,* 2009). Impaired delivery of Cu can result in decreased cuproenzyme activity, the skeletal and vascular systems (Failla *et al.,* 2001). Anaemia, neutropenia and osteoporosis are caused by a lack of copper (Angelova *et al.,* 2011). Accumulation of Cu can trigger the Mense disease which is classified as one of a fatal disorder (Gu *et al.,* 2002). Wilson disease also could occur due to Cu accumulates in the brain and eyes in the form of Kayaer-Fleischer ring (Attri *et al.,* 2006; Sarkar, 1999). Kidney damage and even death could happen due to excessive intake of Cu (Dorsey *et al*., 2004).

Besides, mercury (Hg) is a non-essential element. In human, Hg can cause the development of fetus destroyed due to their toxicity and also considered as a carcinogenic (Ikem and Egilla, 2008). While Vettori *et al.,* (2003) studied due to the Hg poisoning, neuronal loss in the cerebellum granule layer and damage of discrete visual cortex area occurs in the adult brain.

Cd is known as non-essential metal that can cause breast cancer and prostate cancer in humans (Chaudhari *et al.,* 2012). Cd also causes damage in kidney, hypertension, tumours, infertility in the reproductive system and hepatic dysfunction (Chaudhari *et al.,* 2012; Rahman and Islam. 2011; Hao *et al.,* 2013).

In addition, lead (Pb) is a naturally-occurring and industrially-produced element that is very toxic to the human, especially children (Koyashiki *et al.,* 2010). Pb can be found in the air. The fetal brain presents a greater sensitivity to the toxic effects of Pb as compared to the mature brain in adults (Schnaas *et al.,* 2006). Umar *et al.,* (2001) stated that symptoms of an anaemic condition, intestinal cramps and fatigue caused by the poisoning of Pb. Pb also can cause toxicity to kidney and nerve tissues (García-lestón *et al.,* 2010). Nowadays, Arsenic (As) is widely spread in the environment (Rahman *et al.,* 2012). As is a carcinogen and toxic to the organisms. As also has the probability to destroy communities in ecology (Sadiq *et al.,* 2003). Toxicity of As depends on the speciation (Devesa *et al.* 2008). Trivalent As (III) has the greatest toxicity. According to ATSDR (2000), mono and dimethyl arsenic have low toxicity.

Air pollution

The air composition consists of 78.0 % nitrogen, 21.0 % of oxygen and 1.0 % mixture of carbon dioxide, water vapour and small quantities of other gaseous (Ashikin *et al.,* 2014). The atmosphere consists of the troposphere (a dense layer that closest to the Earth), stratosphere (less dense gaseous layer and more distant from the Earth), and the ionosphere (ionized gaseous) (Enger and Smith, 2000).

The atmosphere also contains non-gaseous materials present in the form of solid or liquid particles dispersed into the air, such as aerosols or particulate matter (Kemp, 2004).

Kemp (2004), also stated that they are often regarded as synonymous with air pollution, although the elements involved like dust, smoke and salt particles are regularly produced by a natural process such as volcanic activity. The normal biological processes create and release spores, pollen grains, bacteria, viruses and a variety of other microscopic particles. The atmosphere is very important as it performs several functions that have allowed humans to survive and develop almost anywhere on the earth's surface (Kemp, 2004).

Pollution, an unwanted destruction of the natural environment by human and naturally induced insults, is a problem facing the present world. The number of people is rapidly growing, due to the expansion of the world population. It is accepted that pollution is a problem, not for a specific group but for everyone. Enger and Smith (2000), stated that pollution as something that people produce in large enough quantities that it interferes with our health and vitality as well. The contributing factors toward pollution are the population's size and the development of technology that lead to the methods utilized to develop pollution (Enger and Smith, 2000).

Pollution is a product from the inefficiency of human developed processes. Raw materials extraction, product manufacturing and power necessary for the processes in manufacturing leading to a considerable

amount of waste (pollution) that is no longer of use (Wagner, 1994). Air pollution is physical or chemical changes brought about by natural processes or human activities that result in air quality degradation (Cunningham *et al.,* 2005). The release of large amounts of smoke and other forms of gaseous waste into the air caused an unhealthy ambient. This is because the pollutants were released faster than they could be absorbed and dispersed by the atmosphere (Enger and Smith, 2000). Dispersion through the air is the fastest way of distribution rather than liquid and solid medium.

Regarding history, people have long recognized the existence of atmospheric pollutants, both natural and anthropogenic effect (Botkin and Keller, 2007). In 1550, Leonardo da Vinci wrote that a blue haze formed from materials emitted into the atmosphere from trees. The air pollution is classified into three types which are named as the Natural Pollutants, Primary Pollutants and Secondary Pollutants. Natural Pollutants are referred to natural phenomena of pollutants that find their way into the atmosphere. Some examples of the natural pollutants are forest fires started by lightning or dispersal of pollen.

These materials can interact with one another in the presence of an energy source to form new secondary air pollutants such as ozone, very reactive materials and natural chemicals in the atmosphere.

CONCLUSION

In summary, the application of the different analytical technique to perform modern chemical tests for indicating the presence of heavy metals in the air are studied in order to know the better one. On the other hand, people all over the world should have a personal concern on how to reduce and get rid of air pollution in human's biome. Health institutions, public and private organizations must have continuous communication about the risk of air pollution towards human health as well.

ACKNOWLEDGEMENT

This work is fully supported by the University Research Fund (Grant no.: UniSZA/2016/DPU/01). The authors fully acknowledged Universiti Sultan Zainal Abidin for fund approval and those who are directly or indirectly involved.

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