ENVIRONMENTAL IMPACTS OF HEAVY METALS CONTAMINATION IN RECYCLED PLASTICS: A PRELIMINARY STUDY

*Aliyu Danmusa Mohammed, Abubakar Ubaidu Usman and Amina Sada
Department of Chemistry, Umaru Musa Yar'adua University, Katsina, Katsina State, Nigeria
*Corresponding Author: aly27moh27@gmail.com

ABSTRACT

Plastics materials used for packaging foods, drugs and other items were analysed to determine possible heavy metals contamination. The plastics are mostly recycled for economic gain and environmental concern. In this work, inductively-coupled mass spectrometer (ICP-MS) was used to determine the heavy metals. It was found that some of these to-be recycled waste plastics contained high concentration of some heavy metals. Out of the four heavy metals (zinc, copper, iron and chromium) analysed, one of the samples contained > 1.00 ppm of chromium and iron. The concentration of chromium in the sample was 1.057 ppm and 1.029 ppm for iron. The concentrations exceeded the permissible concentration recommended by World Health Organisation (WHO): 0.1 ppm and 1.0 ppm for chromium and iron respectively.

Keywords: Concentration, environment, heavy metals, ICP-MS, packaging-plastics, plastic waste.

INTRODUCTION

Plastics are one of the most widely used materials in the world today. They have versatile applications in various sectors due to their physico-mechanical properties. On the other hand the end-use poses a serious environmental threat. For instance, packaging accounts for 31% of municipal solid waste [1]. However, researchers have come up with several ways to curb the menace of plastics waste. The three major ways to manage solid waste are to recycle or incinerate it, or to send it to a landfill.

Due to decreasing landfill space, organizations such as the Environmental Protection Agency (EPA) of the United States of America, have been encouraging the use of recyclable thermoplastic materials to reduce impacts on future generations [1]. For instance, recycled polyethylene terephthalate (RPET) is commonly used for direct food-contact packaging, but, there has been limited legislative monitoring of the contaminants in the plastics used for this purpose in Nigeria. Mechanical recycling practices use 95% of the recycled PET drinking bottles and, as a result RPET may be contaminated with materials such as polyvinyl chloride (PVC), nylon, and heavy metals [2]. PET is a versatile plastic commonly used for food-contact containers and films [3]. It is a thermoplastic that possesses excellent thermal and mechanical properties. In 2008, world-wide consumption of PET was over 15 million tons [4]. Most of the PET resin was sold as food-grade material for beverage and other direct food-contact uses.

These contaminants come from numerous sources including labels, adhesives, inks, and debris during transport and sorting. A study (using ICP-MS and ICP-AES) confirmed the presence of lead, chromium and cadmium in food packaging [5]. These metals have the potential to migrate onto and into food if not separated by a functional barrier. Another report suggested increased migration of these contaminants with the increased use of recycled content [6].

The Agency for Toxic Substances and Disease Registry have stated that at certain concentrations or with prolonged exposure/ingestion, heavy metals have the potential to cause serious health effects [7, 8].

Based on the high probability of potential toxicity effect of heavy metal as a result of consumption of packaged food, there is a need to test and analyze these materials to ensure that the levels of these elements do not reach the hazardous level.

The environmental concern about possible heavy metals contamination on recycled plastics is what triggers this work. As stated earlier, the need for environmental management and waste control coupled with economic benefits have made recycling of waste plastics a common operation in plastics industries. Heavy metals have become a public health concern due to their toxicity, bioaccumulation in the food chain [9, 10]. Similar studies have shown that when plastics are released into the environment, heavy metals may leach into the surrounding, representing a source of contamination [11-13]. Moreover, it has been reported that in aquatic environment, plastics are readily contaminated with heavy metals when the time of exposure is longer [14].

In this work, plastic bottles were collected and analysed to quantify the presence of some heavy metals using an inductively coupled plasma-mass spectrophotometer (ICP-MS). It is focused on plastics that are disposed on lands as wastes and are often recycled for further applications by the industries.

MATERIALS AND METHODS

MATERIALS

Pestle and mortar, crucible and thermometer; nitric acid (Sigma-aldrich), distilled water and detergent. The instrument used is Agilent 7500CE ICP-MS and it was run at the following experimental conditions: RF Power: 1550 W, Sample depth: 8 mm, Carrier gas: 1 L/min, Makeup Gas: 0.17 L/min, S/C Temp: 2 °C.

Sample collection and preparation

The samples were collected from Kofar Marusa and Kofar Kaura areas of Katsina Local Government Area of Katsina State, Nigeria. Plastics samples disposed in the streets and consisting of high density polyethylene (HDPE) used for packaging milks (milk jugs) and food wrapping were selected in all the sampling areas. The samples were cut to smaller pieces and then heated. The essence of heating the plastic is to soften and deform it so that they become brittle and breakable after cooling.

The plastic were pulverized with a mortar and pestle to make it ideally suited for the preliminary size reduction and homogenization. The essence is to ensure efficient extraction of additives in the plastic samples and to increase the rate of dissolution of the sample. The pulverized plastic samples were ashed to break down the organic molecules in the plastic and then digested in accordance with CPSP-CH-E1002-08 Test Method [3]. Accurately 4 g each of the ground samples were transferred into a large silica crucible where it was charred on a hot plate till the fume escaped. This is then followed by complete ashing in muffle furnace at 500℃ for 6 hours. The crucible was then taken out of the furnace and kept in desiccators for cooling. After cooling, the samples were powdered and homogenized in the silica crucible.

Acid Digestion of Samples

A method reported by Welle and Franz [4] was used with little modifications. Accurately, 0.2g of the sample was taken in separate silica crucible for acid digestion. Nitric acid (5 mL) was used for digestion. After treating the sample with the acid, the digest was filtered using a filter paper to remove the insoluble particles the solution was raised to 50 mL volume by adding distilled water. Blank sample was also prepared in a similar way. ICP-MS was used to quantitatively analyse the processed samples. The test was carried out in triplicate to minimize error. The results obtained weresubjected to statistical analysis to determine concentration of each heavy metal present.

RESULTS AND DISCUSSION

The concentrations of Fe, Cu, Cr and Zn, in plastic bottles were studied. The results of the level of these heavy metals in used plastic bottles showed that all samples contained Zn, Fe, Cr and Cu in varying concentrations as presented in Table 1.

Table 1: Concentration of some heavy metals in plastics samples collected from different areas

Sample Location	**Zn (ppm)**	**Cu (ppm)**	**Fe (ppm)**	**Cr (ppm)**
KOFAR MARUSA 1(KM1)	0.079±0.0010	0.051±0.0043	0.238±0.0031	0.137±0.0078
KOFAR MARUSA 2 (KM2)	0.139±0.0015	0.031±0.0028	0.293±0.0056	0.108±0.0051
KOFAR KAURA 1 (KK1)	0.287±0.0022	0.047±0.0032	1.057±0.0020	1.029±0.0039
KOFAR KAURA 2 (KK2)	0.283±0.0013	0.045±0.0051	0.788±0.0047	0.801±0.0051

The mean concentration of Zn which is within the range of the allowed limit (1 ppm) by the World Health Organisation (WHO) in the samples follows the order: KK1 >KK2>KM2>KM1 that is 0.287>0.283>0.139>0.079 ppm. The mean concentration of Cu which is also within the allowed limit by WHO in the samples follows the order: KM1>KK1 >KK2>KM2> that is 0.051>0.047ppm>0.045>0.031 ppm. The concentration of these heavy metals in the plastic samples is attributed to environmental contamination of the plastics by the respective heavy metals. Several studies have shown that heavy metals are present in the environment at different concentration and that these metals can migrate and contaminate food, water and other materials.

The mean concentration of iron and chromium were within the permissible limit set by WHO for the samples collected from three areas with the exception of one sample collected from one area, which contained a relatively higher concentration of the heavy metals above permissible limit 1.057 and 1.029 ppm for Fe and Cr respectively. This may occur as a result of the plastic bottles been disposed in an environment containing these contaminants, and as such got their way into the packaging materials.

CONCLUSION

This research work has shown that proper analysis of plastics should be properly carried out before being recycled for future use. In this work it has been found that some heavy metals are present in plastic materials use for food packaging, with concentration of some metals higher than the permissible limit set by the world health organization (WHO). There may have been possible contamination of the waste plastics by heavy metals present in the environment and other sources.

REFERENCES

[1]. Marsh, K. & Bugusu, B. (2007). Food packaging – roles, materials, environmental issues. *J Food Sci*. 72(3), R39–R55.

[2]. Curtzwiler, G., Vorst, K., Danes, J.E., Auras, R. & Singh. J. (2011). Effect of recycled poly(ethylene terephthalate) content on properties of extruded poly(ethylene terephthalate) sheets. *Journal of Plastic Film and Sheeting*, (1-2), 65-86.

[3].Cheng, C., Shi, H., Adams, C. & Ma, Y. (2010). Assessment of metal contaminations leaching out from recycling plastic bottles upon treatments. *Environmental Science and Pollution Research International*, 17, 1323.

[4].Welle, F. & Franz, F. (2011). Migration of antimony from PET bottles into beverages: determination of the activation of energy of diffusion and migration modeling compared with literature data. *Food Additives and Contaminants*, 28(1), 115-126.

[5]. Lenntech (2004). Water Treatment and Air Purification, Water Treatment, Publish by Lenntech, Rotterdamseweg, Netherlands.

[6]. Vergnaud, J.M. (1998). Problems encountered for food safety with polymer packages: chemical exchange, recycling. *Advances in Colloid and Interface Science*, 78(13), 267–297.

[7]. Jarup, L. (2003). Hazards of heavy metal contamination. *Br Med Bull*. 68, 167–182.

[8]. California Health and Safety Code. (2009). Section 25214.11-25214.26: Article 10.4. Toxics in packaging prevention act. California Department of Toxic Substances Control.

[9]. Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K. & Sutton, D.J., (2012). Heavy metal Toxicity and the environment. EXS. https://doi.org/10.1007/978-3-7643-8340-4_6.

[10]. Yadav, M., Gupta, R. & Sharma, R.K.(2018). Chapter 14 - green and sustainable Pathways for wastewater purification. In: Advances in Water Purification Techniques: Meeting the Needs of Developed and Developing Countries. Elsevier, pp. 355–383. https://doi.org/10.1016/B978-0-12-814790-0.00014-4.

[11]. Nakashima, E., Isobe, A., Kako, S., Itai, T. & Takahashi, S. (2012). Quantification of Toxic metals derived from macroplastic litter on Ookushi beach, Japan. *Environ. Sci.Technol.* 46, 10099.

[12]. Richard, H., Carpenter, E.J., Komada, T., Palmer, P.T. &Rochman, C.M. (2019). Biofilm facilitates metal accumulation onto microplastics in estuarine waters. *Sci. Total Environ.* 683, 600–608. https://doi.org/10.1016/j.scitotenv.2019.04.331.

[13]. Turner, A. & Lau, K.S. (2016). Elemental concentrations and bioaccessibilities in Beached plastic foam litter, with particular reference to lead in polyurethane. *Mar. Pollut.Bull.* 112, 265–270. https://doi.org/10.1016/j.marpolbul.2016.08.005.

[14]. Rochman, C.M., Hentschel, B.T. & Teh, S.J. (2014). Long-term sorption of metals is Similar among plastic types: implications for plastic debris in aquatic environments. PLoS One 9, 1.