A comparative analysis of heavy metals present in cigarette and cigarette leachate

Maria Michal

Christ University

Anu Maria

Christ University

Krishnakumar Velayudhannair (✉ krishnakumar.v@christuniversity.in)

Christ University <https://orcid.org/0000-0002-2183-4632>

Xavier Vincent

Christ University

Divya K. Radhakrishnan

Kerala University of Fisheries and Ocean Studies

Research Article

Keywords: heavy metals, cigarette, aquatic pollution, environment, aquatic organisms

Posted Date: April 12th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-356726/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Smoked cigarette and butts are the most common forms of litter globally. The local water bodies and their compartments have been severely polluted by the accumulation of these litters and the cumulative effect of many cigarette butts littered in a centralised area may present a significant threat to the living organisms. It is essential to study the leaching behaviour of cigarettes to understand how the heavy metals are leached out into the aquatic ecosystem. In this context, we determined the concentration of different metals (such as Cd, Cu, Fe, Pb, Sn, Zn & Hg) leached from the different brands of unsmoked and smoked cigarette and cigarette butts by using Atomic Absorption Spectrometry. The results revealed that the amounts of heavy metal are higher in butt samples (USB and SB) of both cigarette and leachate irrespective of brands, compared to the tobacco part of the cigarette and the concentrations of certain toxic heavy metals in cigarettes were significantly different between cigarette brands tested. These results suggest that cigarette litter was found to be one of the major sources of metal contamination in the aquatic ecosystem and apparent leaching may increase the risk of toxicity to aquatic organisms.

Introduction

Smoked cigarette and butts are the most common forms of litter globally, where the common people can be present, especially on the waterways, the roads, the parks etc. (Habre et al. 2014; Robinson 2005). About 6 trillion cigarettes are found to be smoking every year globally and one of the largest wastes generated in our society, which represent around 13% of total items collected in the international coastal cleanup (Mohajerani 2016) thrice as much as any other type of litter. The local water bodies and their compartments have been severely polluted by the accumulation of these litters (El Tokhi 2017) and the cumulative effect of many cigarette butts littered in a centralised area may present a significant threat to the living organisms (Slaughter et al. 2011; Micevska 2006).

There are two types of cigarette smoking, mainstream smoking (MSS), the smoke inhaled by the smoker, and sidestream smoking (SSS), the smoke is released from the tip of the cigarette in between puffs. Several studies say that SSS contains higher levels of a cancer-causing substance (Micevska 2006). Although the presence of various compounds present in cigarettes and butts and mainstream smoke have been extensively studied, a few reports are available on the amount of these components leached from cigarette and cigarette butts (Micevska 2006; Moriwaki 2009). The heavy metals and trace elements present in the cigarette butt leachates are the reason for the toxicity in the organisms (Micevska 2006). The occurrence of heavy metals in cigarettes is largely due to the soil condition where the tobacco (*Nicotiana tabacum*) is being cultivated (Talhout et al. 2011; Register 2000). Apart from that, the application of pesticides, insecticides and herbicides also introduce metals to the tobacco leaf (Ontario 1994). Also, metals are accumulated during the manufacturing of cigarette, essentially through the addition of casing materials to the cured leaves (Baker et al. 2004a, b) and the use of brightening agents on the wrapping paper (Mussalo-Rauhamaa et al. 1986; Iskander et al. 1986; Iskander 1985; Owens 1978). Most of the chemicals produce new compounds when it is burned (Novotny et al. 2011, 2009).

Due to the accumulation of various heavy metals in the water bodies, the response of aquatic biota to heavy metal contamination is highly varied (Kabata-Pendias and Pendias 2001; Mason 1991). Also, physical parameters, such as pH, affect the mobility of metals in the sediments further influence the biological responses and the bioavailability of metals to the aquatic organisms, including plants (Kabata-Pendias and Pendias 2001). It is essential to study the leaching behaviour of cigarettes to understand how the heavy metals are leached out into the aquatic ecosystem. In this context, the present study aims to determine the concentration of different metals such as Cd, Cu, Fe, Pb, Sn, Zn and Hg leached from the different brands of unsmoked and smoked cigarette and cigarette butts in an aqueous solution and to assess the concentration of metals leached concerning the soaking time of the cigarette samples. The selection of the above metals for the study is based on their presence in smoked filters (Dobaradaran et al. 2017; Mindell 2001; Chiba and Masironi 1992) toxicity to living organisms (Savino and Tanabe 1989).

Materials And Methods

Sampling of cigarettes

Packs of the three most popular tobacco cigarette brands were purchased from the local shops in Bengaluru, South India. Following collection, the filters and the tobacco part of the cigarettes were cut and separated manually. Cigarettes were sampled as an unsmoked cigarette (USC), smoked cigarette (SC), unsmoked butt (USB) and smoked butt (SB) from each brand (See further) (Fig. 1a). All these samples were stored separately in disposable plastic containers to prevent contamination and moistening caused by humidity in the laboratory.

- Unsmoked cigarette (USC): The cigarettes were cut, without smoking, at 1/3 from the top of the cigarette using a sterile scissor and the remaining part (including tobacco and butt) was sampled as USC.
- Smoked Cigarette (SC): Cigarettes were smoked artificially till half of the cigarette (1/3 from the top) and the remaining part was sampled as SC.
- Unsmoked Butt (USB): The filter (butt) part of the cigarette was cut and removed and sampled as USB.
- Smoked Butt (SB): Cigarettes were smoked artificially till the butt and sampled as SB.

Smoking of cigarettes

The cigarettes were artificially smoked as per Micevska et al. (2006). Briefly, five cigarettes from all the three different brands were smoked separately by placing a lit of cigarette against vacuum, using a plastic bottle filled with water fitted provided with an outlet at the hind end of the bottle (Fig. 2). The on and off outlet of water helps in mimicking the action of a smoker (Micevska 2006). The cigarettes were smoked down from the top as mentioned in the previous section.

Preparation of leachates

Leachates of all the above four samples (USB, SB, USC and SC) of three different brands were prepared separately by adding them to the phials of an aqueous solution. All the samples (USC, SC, USB and SB) were allowed to soak in the aqueous solutions for 24 hours. Five duplicates were taken for each sample. Blank was also prepared in the same manner without the addition of any cigarette material (Slaughter et al. 2011). This procedure is summarized in Fig. 1b.

Heavy metal analysis in cigarette samples

For the analysis of heavy metals present in the different samples of cigarette brands, Eneji et al. (2013) methods was followed. All the samples were cut into tiny pieces using scissors and were washed with about 4ml of 1% HNO_3 . The samples were placed in a muffle furnace using a crucible. The muffle furnace was set at 500°C for 1 hour. The ignited residues were moistened with water. To this, 5ml of 4N HCl was added carefully and the mixture was filtered through Whatman filter paper into a 50 ml volumetric flask. This was diluted to the mark and stored in 4°C for analysis using Atomic Absorption Spectroscopy (AAS model AAA 6880 Shimadzu, with a measurement range of 185–900 nm, photomultiplier tube detector, flame type: Air-C 2H_2) (Eneji et al. 2013).

Acid digestion of cigarette leachates

Fifty millilitres of leachate were prepared per sample and were subjected to acid digestion using concentrated H_2SO_4 and concentrated HNO_3 . All glassware and containers used for the process of acid digestion were washed with 1% HNO_3 before the treatment. To the sample, 0.5ml of concentrated H_2SO_4 and 1ml of concentrated HNO_3 was added and were incubated for 4 hours in a boiling water bath (Matsunaga et al. 1979). After completion of the four hours, the digested samples were filtered into a 50ml volumetric flask using Whatman filter paper. The solution was diluted to 50ml using distilled water and it was stored at 4°C for further analysis using Atomic Absorption Spectroscopy (Model AAA 6880, Shimadzu).

Statistical analysis

All the data were subjected to statistical analysis. Microsoft Excel software was used for statistical analysis. The tools like standard deviation and mean was found out for all the samples and significant variation was found out using a graph.

Results

The levels of different heavy metals, such as Cd, Cu, Fe, Pb, Sn, Hg and Zn present in the three different popular brands of cigarettes sold in Bengaluru, Southern India, and were classified based on the selling price as expensive, moderate and cheap. Each brand has four samples, like unsmoked cigarette (USC), smoked cigarette (SC), unsmoked butt (USB) and smoked butt (SB). Heavy metals present in these samples (direct) and leachate were analyzed.

Levels of heavy metals in the different samples of expensive brand

In this brand, the level of Cd was found to be highest in SB ($0.52 \pm 0.01 \mu\text{g/g}$), while the least level was recorded with USC and USB (0.25 ± 0.03 and $0.24 \pm 0.02 \mu\text{g/g}$ respectively). Statistical analysis reveals that the difference in the level of Cd between SB and other samples are significant ($P < 0.05$) whereas the difference between SC and USB and USC are insignificant ($P > 0.05$). Among the four samples, the USB and SB registered with the highest level of Cu (151.30 ± 5.76 and $162.94 \pm 6.80 \mu\text{g/g}$ respectively), while the samples SC and USC registered a low level of Cu (73.79 ± 0.36 and $86.61 \pm 0.91 \mu\text{g/g}$ respectively). The statistical analysis revealed that there is a significant difference ($P < 0.05$) between butts and cigarettes whereas the difference between USB and SB and USC and SC is insignificant ($P > 0.05$). The level of iron (Fe) was found to be highest in the USC ($105.48 \pm 0.39 \mu\text{g/g}$), followed by SC and USB (87.93 ± 3.56 and $51.15 \pm 2.04 \mu\text{g/g}$ respectively). The statistical analysis revealed that there is a significant difference ($P < 0.05$) between the different four samples. The level of lead (Pb) was found to be highest in SB ($19.86 \pm 2.39 \mu\text{g/g}$), followed by USB and SC (16.97 ± 1.46 and $12.44 \pm 1.40 \mu\text{g/g}$ respectively). The least level of Pb is found in USC ($9.97 \pm 0.49 \mu\text{g/g}$). The statistical analysis on the level of Pb between the samples was significant ($P < 0.05$). The level of tin (Sn) showed the highest trend SB ($869.05 \pm 19.11 \mu\text{g/g}$), followed by USB and SC. The least level of Sn is in USC with an insignificant difference, while USC and SC (599.60 ± 15.98 and $466.88 \pm 8.33 \mu\text{g/g}$ respectively). It was revealed that USC has registered the lowest level for Sn ($438.32 \pm 2.89 \mu\text{g/g}$). Statistical analysis on the level of Sn between the samples was significant ($P < 0.05$). The level of zinc (Zn) was found to be high in USB ($45.21 \pm 1.48 \mu\text{g/g}$) while the least level of Zn was found in SC ($24.40 \pm 0.71 \mu\text{g/g}$). The sample USC ($305.34 \pm 8.14 \mu\text{g/g}$), showed a high amount of Hg while SC least amount of Hg ($104.78 \pm 3.08 \mu\text{g/g}$), with significant difference ($P < 0.05$) (Fig. 3).

Levels of heavy metals in different samples of a moderate brand

The level of Cd was found to be high in the samples SB and USB (1.18 ± 0.08 , $1.15 \pm 0.07 \mu\text{g/g}$ respectively), while the least level of Cd was found in USC and SC (0.56 ± 0.01 , $0.55 \pm 0.08 \mu\text{g/g}$ respectively). Statistical analysis reveals that the difference in the level of Cd between butts and cigarettes are significant ($P < 0.05$) whereas the difference between SB and USB and USC and SC is insignificant ($P > 0.05$). Among the four samples, the USB registered with the highest level of Cu ($287.530 \pm 43.29 \mu\text{g/g}$) followed by the SB ($185.35 \pm 15.00 \mu\text{g/g}$), while the samples SC and USC registered a low level of Cu (96.85 ± 6.04 and $105.07 \pm 8.51 \mu\text{g/g}$ respectively). The level of iron (Fe) was found to be high in the SB ($155.30 \pm 5.04 \mu\text{g/g}$) and low in the USB ($112.28 \pm 9.73 \mu\text{g/g}$). The samples USC and SC registered almost similar value (134.61 ± 5.56 and $139.72 \pm 4.34 \mu\text{g/g}$ respectively). The statistical analysis revealed that the difference between the samples SB and USB is significant ($P < 0.05$), but an insignificant difference was observed between the samples USC and SC ($P > 0.05$). The level of lead (Pb) was found to be highest in USB ($24.42 \pm 1.18 \mu\text{g/g}$) and least in SB ($2.76 \pm 0.10 \mu\text{g/g}$), but the samples

USC and SC (14.14 ± 1.07 and 12.70 ± 1.68 $\mu\text{g/g}$) had similar values with an insignificant difference ($P > 0.05$). The statistical analysis on the level of Pb between the samples was significant ($P < 0.05$). The level of tin (Sn) showed the highest trend USB and SB (1184.51 ± 10.82 and 1168.60 ± 15.39 $\mu\text{g/g}$ respectively), with an insignificant difference ($P > 0.05$), while USC and SC have registered low level for Sn (617.69 ± 17.20 and 567.61 ± 11.69 $\mu\text{g/g}$ respectively) and the difference between the samples was insignificant ($P > 0.05$). The level of zinc (Zn) was found to be high in USB (141.92 ± 9.57 $\mu\text{g/g}$) while the least level of Zn was found in SC (37.10 ± 6.79 $\mu\text{g/g}$). The samples SB and USB (359.02 ± 19.05 and 331.38 ± 8.09 $\mu\text{g/g}$ respectively), showed a high amount of Hg while USC and SC had a lesser amount of Hg (140.87 ± 4.36 $\mu\text{g/g}$ and 158.36 ± 5.75 $\mu\text{g/g}$), with the insignificant difference ($P > 0.05$) (Fig. 4).

Levels of heavy metals in the different samples of cheap brand

The level of Cd was found to be high in the samples USC and SB (0.12 ± 0.02 and 0.13 ± 0.01 $\mu\text{g/g}$ respectively), while the least level of Cd was found in USB and SC (0.05 ± 0.0 and 0.07 ± 0.02 $\mu\text{g/g}$ respectively). Statistical analysis reveals that the difference in the level of Cd between USC, SB and USB, SC are significant ($P < 0.05$) whereas the difference between USC and SB and USB and SC is insignificant ($P > 0.05$). Among the four samples, the USB registered with the highest level of Cu (148.00 ± 1.71 $\mu\text{g/g}$) followed by the SB (117.94 ± 11.02 $\mu\text{g/g}$), while the samples USC and SC registered a low level of Cu (63.78 ± 3.45 and 65.18 ± 3.95 $\mu\text{g/g}$ respectively). The level of iron (Fe) was found to be high in the USB (232.88 ± 13.16 $\mu\text{g/g}$), followed by SB (203.82 ± 12.34 $\mu\text{g/g}$). The samples USC and SC registered almost similar value (165.33 ± 3.45 and 161.49 ± 4.61 $\mu\text{g/g}$ respectively). The statistical analysis revealed that the difference between the butts and cigarettes is significant ($P < 0.05$), but an insignificant difference was observed between the samples USC and SC. The level of lead (Pb) was found to be highest in USB (15.84 ± 2.37 $\mu\text{g/g}$), followed by SB and SC (13.69 ± 1.67 and 8.90 ± 1.66 $\mu\text{g/g}$ respectively) and least in USC (5.77 ± 1.33 $\mu\text{g/g}$). The statistical analysis on the level of Pb between the samples was significant ($P < 0.05$). The Sn was found to be undetectable or absent in all the samples. The level of zinc (Zn) was found to be high in USB and SB (39.37 ± 3.43 and 40.93 ± 2.00 $\mu\text{g/g}$) while the least level of Zn was found in USC and SC (29.36 ± 3.03 and 31.89 ± 3.44 $\mu\text{g/g}$). Statistical analysis revealed a significant difference between butts and cigarettes ($P < 0.05$) whereas the difference between USB, SB and USC, SC showed insignificant difference ($P > 0.05$). The levels of Hg was found to be high in USB (205.11 ± 9.62 $\mu\text{g/g}$), followed by SB and USC (141.25 ± 6.23 and 101.34 ± 4.57 $\mu\text{g/g}$ respectively). The least level of Hg was found to be in SC (76.66 ± 0.74 $\mu\text{g/g}$). Statistical analysis revealed that there is a significant difference between the different samples (Fig. 5).

Levels of heavy metals in the leachates of different samples of expensive brand

The levels of Cd was found to be high in USB (0.38 ± 0.01 $\mu\text{g/g}$), followed by USC (0.11 ± 0.0 $\mu\text{g/g}$). The values of Cd present in SB and SC were found to be the same. (0.02 ± 0.0 and 0.02 ± 0.02 $\mu\text{g/g}$ respectively). The statistical analysis of Cd reveals that there was a significant difference between the

levels of USB, USC and the other samples ($P < 0.05$). The levels of Cd was found to be insignificant between the samples SB and SC ($P > 0.05$). Among the four samples, USB registered with the highest level of Cu ($40.15 \pm 1.83 \mu\text{g/g}$) and the least amount was found in SC ($13.45 \pm 11.09 \mu\text{g/g}$). The samples of USC and SB registered with almost similar values. (24.57 ± 3.25 , $23.16 \pm 2.15 \mu\text{g/g}$ respectively). Statistical analysis reveals that there is a significant difference between USB and SC ($P < 0.05$), whereas the levels of Cu between USC and SB is insignificant ($P > 0.05$). The level of iron (Fe) was found to be high in USB and SB (125.75 ± 9.01 , $117.66 \pm 3.46 \mu\text{g/g}$ respectively), followed by USC ($73.62 \pm 0.50 \mu\text{g/g}$). The least level of Fe was found to be in SC ($17.55 \pm 13.20 \mu\text{g/g}$). Statistical analysis reveals that there is a significant difference between butts and cigarettes ($P < 0.05$). The levels of Fe between USB and SB was found to be insignificant ($P > 0.05$), whereas there is a significant difference between levels of Fe between USC and SC ($P < 0.05$). The level of lead (Pb) was found to be highest in USB ($29.25 \pm 3.51 \mu\text{g/g}$), followed by SB, USC and SC (6.38 ± 1.08 and 5.51 ± 0.41 and $2.18 \pm 1.50 \mu\text{g/g}$ respectively). Statistical analysis reveals that there is a significant difference among all four samples ($P < 0.05$). The level of Sn was found to be below the detectable level in all four samples. Among the four samples, a high level of Zn was found to be in USB and SB (31.87 ± 0.54 and $33.0 \pm 2.12 \mu\text{g/g}$ respectively), whereas the samples USC and SC registered with low level of Zn (17.29 ± 0.19 and $11.30 \pm 7.99 \mu\text{g/g}$ respectively). Statistical analysis reveals that there is a significant difference in levels of Zn between the butts and cigarettes ($P < 0.05$), whereas the difference between the sample was found to be insignificant between USB and SB; and USC and SC ($P > 0.05$) (Fig. 6).

Levels of heavy metals in the leachates of different samples of the moderate brand

The level of Cd was found to be high in the sample USB ($0.89 \pm 0.02 \mu\text{g/g}$), followed by SC ($0.12 \pm 0.02 \mu\text{g/g}$). The samples USC and SB had the same level of Cd ($0.05 \pm 0.0 \mu\text{g/g}$). Statistical analysis reveals that the difference in the level of Cd between USB and SC are significant ($P < 0.05$). Among the four samples, the USB registered with the highest level of Cu ($89.15 \pm 3.79 \mu\text{g/g}$) followed by the USC ($25.85 \pm 1.08 \mu\text{g/g}$), while the samples SC and SB registered a low level of Cu (11.69 ± 0.73 and $11.13 \pm 0.26 \mu\text{g/g}$ respectively). The level of iron (Fe) was found to be high in SB and USB (246.37 ± 2.99 , $242.81 \pm 10.59 \mu\text{g/g}$ respectively), followed by USC ($124.58 \pm 5.81 \mu\text{g/g}$). The least level of Cu was found in SC ($105.11 \pm 3.45 \mu\text{g/g}$). The statistical analysis revealed an insignificant difference between the samples SB and USB ($P > 0.05$) and a significant difference is seen in the level of Cu between the butts and cigarettes ($P < 0.05$). The level of lead (Pb) was found to be highest in USB ($128.89 \pm 8.53 \mu\text{g/g}$), followed by SC and SB (21.25 ± 1.32 and $16.29 \pm 0.48 \mu\text{g/g}$ respectively). The least level of Pb was observed in USC ($5.88 \pm 0.36 \mu\text{g/g}$). The statistical analysis on the level of Pb between the samples was significant. The level of tin (Sn) showed the highest trend in USC ($3.64 \pm 0.55 \mu\text{g/g}$). The level of Sn was below detectable range in the samples USB, SB and SC. The level of zinc (Zn) was found to be high in USB ($64.00 \pm 9.28 \mu\text{g/g}$), followed by SB ($40.96 \pm 0.54 \mu\text{g/g}$). The level of Zn was similar for the samples USC and SC (27.74 ± 1.14 and $25.95 \pm 1.36 \mu\text{g/g}$ respectively). Statistical analysis of the levels of Zn showed a significant difference between butts and cigarettes and between USB and SB too ($P < 0.05$) whereas there was no significant difference between USC and SC ($P > 0.05$) (Fig. 7).

Levels of heavy metals in the leachates of different samples of cheap brand

The level of Cd was found to be similar in all the three samples USB, SB, and SC, but reduced significantly in USC. The statistical analysis reveals that there is an insignificant difference among the samples USB, SB, and SC the levels of Cd in the four samples ($P > 0.05$). Among the four samples, the USB registered with the highest level of Cu ($89.76 \pm 0.08 \mu\text{g/g}$), followed by SC and USC (12.05 ± 0.47 and $10.29 \pm 0.50 \mu\text{g/g}$ respectively). In the sample SB, the level of Cu was below the detectable level. The statistical analysis reveals that there is a significant difference between butts and cigarettes. The samples SC and USC showed an insignificant difference in the levels of Cu. The level of iron (Fe) was found to be high in the USB ($769.36 \pm 17.02 \mu\text{g/g}$), followed by USC and SB (191.47 ± 8.41 and $107.62 \pm 0.80 \mu\text{g/g}$ respectively). The least level of Fe was found to be in SC ($66.47 \pm 2.12 \mu\text{g/g}$). Statistical analysis reveals that there is a significant difference in the level of Fe between all four samples. The level of lead (Pb) was found to be highest in SC ($18.06 \pm 1.41 \mu\text{g/g}$), followed by USB and USC (9.68 ± 0.66 and $2.61 \pm 0.29 \mu\text{g/g}$ respectively). The least level of Pb was found to be in SB ($0.83 \pm 0.80 \mu\text{g/g}$) statistical analysis reveals that there is a significant difference between all the four samples ($P < 0.05$). Among the four samples, USB and SB registered a high level of Sn (168.60 ± 9.40 , $153.93 \pm 7.02 \mu\text{g/g}$ respectively), whereas the level of USC and SC was found to contain a lower level of Sn (106.60 ± 2.50 and $103.16 \pm 0.68 \mu\text{g/g}$ respectively). Statistically, there is a significant difference between butts and cigarettes. The level of Sn between the samples USB and SB: USC and SC were found to be insignificant ($P > 0.05$) (Fig. 8).

Discussion

Cigarettes are found to be littered in all places and are become a serious threat to the environment. In the present study, efforts were taken to determine the level of different heavy metals present in popular cigarette brands, that are sold in Bengaluru city, South India and the number of heavy metals leached out into the aquatic medium. For this purpose, popular tobacco cigarette brands were used. Cadmium, Copper, Tin, Lead, Iron, Mercury and Zinc present in the samples was analyzed.

Cigarette litter, both smoked cigarette and butt, thrown into the environment encompass a wide range of cigarette brands with varying amounts of tobacco left on the filters. In this study, smoked cigarette material and butts were collected due to their popularity and use to provide a sample population representative of the local cigarette litter concerning the brand and amount of remnant tobacco, but the metal concentrations in cigarettes may vary among the brands. The relative percentage of the mean value with a standard deviation of heavy metal present and leached is relatively low for most sample sets, demonstrating the reproducibility of this method. The leaching procedure employed in this preliminary study is not an open system to mimic the natural environment, but a closed system is the most straightforward method of obtaining the maximum amount of leachable metal. Another disadvantage of this study is lacking information on the interactions of various other physicochemical parameters such as pH, temperature etc.

Among the samples analyzed, the mean of lead (Pb) was found to be highest in the present study compared with previous studies. The mean amount was found to be 16.85 µg/g with a minimum amount of 0.834 µg/g and a maximum of 128.893 µg/g and the amount was found to be more in the leachates of the cigarette sample. This was much higher than other reports (Janaydeh et al. 2019; Engida and Chandravanshi 2017; Sebiawu et al. 2014; Ashraf, 2012; Kazi et al. 2009; Raju et al. 1999). In the present study, a mean of 78.98 µg/g of copper with a maximum of 287.52 µg/g was observed and this level was several folds higher than other reports (Dobaradaran et al. 2017; Engida and Chandravanshi 2017; Sebiawu et al. 2014; Raju et al. 1999). Similar results were observed with Hg (Phal 2011; Kowalski and Wierciński 2009; Raju et al. 1999). Whereas the Fe (Dobaradaran et al. 2017; Engida and Chandravanshi 2017; Sebiawu et al. 2014; Raju et al. 1999), Cd (Dobaradaran et al. 2017; Janaydeh et al. 2019; Engida and Chandravanshi 2017; Sebiawu et al. 2014; Ashraf 2012; Eneji et al. 2013; Kazi et al. 2009; Raju et al. 1999) content reported in the present was comparatively lesser. This may be due to the difference in leaching methods employed and the number of samples used.

Leachates of unsmoked cigarettes and butts were investigated in the present study to provide concentrations of the metals of interest leached out into the environment and to identify possible instances of contamination. In general, the metal concentrations of the leachates prepared from the butt were higher than those present in the leachates prepared from cigarettes. This difference may be due to the loss of heavy metals in smoke or ash during cigarette combustion (Zulfiqar et al. 2006; Benner et al. 1989). But Hg and Sn were not present in the leachate, whereas the presence of these metals could be observed in the direct samples (without leaching). This may be due to not leaching these heavy metals in 24hrs. If the butts kept more days in the water, then they may leach. For local aquatic organisms sensitive to Pb, Cd and Zn, a rapid release of these metals may have implications for acute biological effects.

The results of this study also revealed that concentrations of metals were higher in general leached from unsmoked cigarettes than smoked cigarette materials implies that cigarette litter with more remnant tobacco likely causes greater contamination than butts with little or no remnant tobacco. This result calls into question a practice of some environmentally conscious smokers, who scatter remnant tobacco into the environment but keep the filter until it can be deposited into a waste container.

Conclusions

We have compared the level of heavy metal present and leached from both cigarette and butt into the aquatic ecosystem. The results revealed that the butt of both smoked and unsmoked samples (SB and USB) contains more heavy metals compared to the tobacco part of a cigarette and releasing a relatively higher concentration of heavy metals in the aquatic ecosystem. Furthermore, the apparent rapid leaching of heavy metals from littered cigarette and butts samples increases the potential for acute toxicity to aquatic life. Hence, further studies are highly warranted to assess the effect of heavy metal leached from the littered cigarette butts on aquatic life and the environment in general.

Declarations

Acknowledgements

The authors gratefully acknowledge Fr. Jobi Xavier, Head of the Department for extending necessary facilities and Mr Jyothis Devasia, Technical Assistant, Central Instrumentation Laboratory, for his technical support in assessing the heavy metals.

Declarations

Funding: This research received no funding

Conflicts of interest/Competing interests: All the authors declares that they have no conflicts of interest

Availability of data and material: All data generated or analyzed during this study are included as in this published article (and its supplementary information files).

Code availability: Not applicable

Authors' contributions: The author's contributions in the article are as follows: Conceptualization: [KV], [XV]; Methodology: [MM] [KV], [DKR]; Formal analysis and data curation: [MM], [AM]; Supervision: [KV]; Writing original draft: [MM], [AM], [KV]; review and editing: [KV], [DKR] [XV]. All authors have read and agreed to the published version of the manuscript.

Ethics approval: Not applicable

Consent to participate: Not applicable

Consent for publication: Not applicable

References

Ashraf MW (2012) Levels of heavy metals in popular cigarette brands and exposure to these metals via smoking. Sci World J 2012 <https://doi.org/10.1100/2012/729430>.

Baker RR, da Silva JRP, Smith G (2004a) The effect of tobacco ingredients on smoke chemistry. Part I: Flavourings and additives. Food Chem Toxicol 42: 3-37. [https://doi.org/10.1016/S0278-6915\(03\)00189-3](https://doi.org/10.1016/S0278-6915(03)00189-3)

Baker RR, da Silva JRP, Smith G (2004b) The effect of tobacco ingredients on smoke chemistry. Part II: casing ingredients. Food Chem Toxicol 42:39-52. <https://doi.org/10.1016/j.fct.2003.08.009>

Benner CL, Bayona JM, Caka FM, Tang H, Lewis L, Crawford J, et al. (1989). Chemical composition of environmental tobacco smoke. 2. Particulate-phase compounds. Environ Sci Technol 23(6):688-699. <https://doi.org/10.1021/es00064a007>

Chiba M, Masironi R (1992) Toxic and trace elements in tobacco and tobacco smoke. Bull World Health Organ 70(2): 269.

- Dobaradaran S, Nabipour I, Saeedi R, Ostovar A, Khorsand M, Khajeahmadi N et al. (2017) Association of metals (Cd, Fe, As, Ni, Cu, Zn and Mn) with cigarette butts in northern part of the Persian Gulf. *Tob Control*, 26(4), 461-463. <http://dx.doi.org/10.1136/tobaccocontrol-2016-052931>.
- El Tokhi M, Amin BM, Alaabed SA (2017) Environmental assessment of heavy metals contamination of bottom sediments of Oman Gulf, United Arab Emirates. *J Pollut Eff Cont* 5(4):203. <https://doi.org/10.4176/2375-4397.1000203>.
- Eneji IS, Salawu OW, Sha'Ato R (2013) Analysis of heavy metals in selected cigarettes and tobacco leaves in Benue State, Nigeria. *World J Med Med Sci Res* 1: 033-037.
- Engida AM, Chandravanshi BS (2017) Assessment of heavy metals in tobacco of cigarettes commonly sold in Ethiopia. *Chem Int* 3(3): 212-8. <https://doi.org/10.31221/osf.io/w958z>.
- Habre R, Coull B, Moshier E, Godbold J, Grunin A, Nath A, et al. (2014) Sources of indoor air pollution in New York City residences of asthmatic children. *J Expo Sci Environ Epid* 24(3):269-278. <https://doi.org/10.1038/jes.2013.74>
- Iskander F (1985) Egyptian and foreign cigarettes: I. Determination of trace elements in cigarette filter before and after smoking. *J Radioanal Nucl Chem* 91(1): 191-196. <https://doi.org/10.1007/BF02036326>.
- Iskander F (1986) Egyptian and foreign cigarettes: II. Determination of trace elements in tobacco, ash and wrapping paper. *J Radioanal Nucl Chem* 97(1): 107-112.
- Janaydeh M, Ismail A, Zulkifli SZ, Omar H (2019). Toxic heavy metal (Pb and Cd) content in tobacco cigarette brands in Selangor state, Peninsular Malaysia. *Environ Monit Assess* 191(10):1-8. <https://doi.org/10.1007/s10661-019-7755-y>.
- Kabata-Pendias A, Pendias H (2001) Trace elements in soils and plants, 3rd edn CRC Press. Boca Raton, FL, USA.
- Kazi TG, Jalbani N, Arain MB, Jamali MK, Afridi HI, Shah AQ (2009) Determination of toxic elements in different brands of cigarette by atomic absorption spectrometry using ultrasonic assisted acid digestion. *Environ Monit Assess* 154(1): 155-167. <https://doi.org/10.1007/s10661-008-0386-3>
- Kowalski R, Wierciński J (2009) Mercury content in smoke and tobacco from selected cigarette brands. *Ecol Chem Eng S* 16(2): 155-162
- Mason CF (1991) *Biology of Freshwater Pollution*. 2nd edn Essex, UK: Longman Group
- Matsunaga K, Konishi S, Nishimura M (1979) Possible errors caused prior to measurement of mercury in natural waters with special reference to seawater. *Environ Sci Technol* 13(1):63-65. <https://doi.org/10.1021/es60149a013>

Micevska T, Warne MSJ, Pablo F, Patra R (2006) Variation in, and causes of, toxicity of cigarette butts to a cladoceran and microtox. *Arch Environ Contam Toxicol* 50(2):205-212. <https://doi.org/10.1007/s00244-004-0132-y>.

Mindell J (2001) Lessons from tobacco control for advocates of healthy transport. *J Public Health* 23(2): 91-97. <http://dx.doi.org/10.1093/pubmed/23.2.91>

Mohajerani A, Kadir AA, Larobina L (2016) A practical proposal for solving the world's cigarette butt problem: Recycling in fired clay bricks. *Waste Manage* 52:228-244. <https://doi.org/10.1016/j.wasman.2016.03.012>

Moriwaki H, Kitajima S, Katahira K (2009) Waste on the roadside,'poi-sute'waste: its distribution and elution potential of pollutants into environment. *Waste Manage* 29(3):1192-1197. <https://doi.org/10.1016/j.wasman.2008.08.017>

Mussalo-Rauhamaa H, Salmela SS, Leppänen A, Pyysalo H (1986) Cigarettes as a source of some trace and heavy metals and pesticides in man. *Arch Environ Health Int J* 41(1):49-55. <https://doi.org/10.1080/00039896.1986.9935765>.

Novotny TE, Lum K, Smith E, Wang V, Barnes R (2009) Cigarettes butts and the case for an environmental policy on hazardous cigarette waste. *Int J Environ Res Public Health* 6(5):1691-1705. <https://doi.org/10.3390/ijerph6051691>

Novotny TE, Hardin SN, Hovda LR, Novotny DJ, McLean MK, Khan S (2011) Tobacco and cigarette butt consumption in humans and animals. *Tob Control* 20 (Suppl 1): i17-i20. <http://dx.doi.org/10.1136/tc.2011.043489>

Ontario (1994). Ministry of Agriculture, Food and Rural Affairs. Policy Analysis Branch. Survey of Pesticide Use in Ontario, 1993: Estimates of Pesticides Used on Field Crops, Fruit and Vegetable Crops, Provincial Highway Roadsides, and by Licensed Pesticide Applicators. Policy Analysis Branch, Ontario Ministry of Agriculture, Food and Rural Affairs

Owens WF (1978) Effect of cigarette paper on smoke yield and composition. *Recent Advances in Tobacco Science* 4: 3-24.

Phal DA (2011) A comparative study of elemental analysis in mosquito repellent coil and cigarette smoke. *Int J Pharm Biol Sci* 1(4): 462-467.

Raju NJ, Kofod M, Isenbeck-Schröter M, Müller G (1999) Heavy metal content of Indian cigarettes. *Toxicol Environ Chem* 72(3-4): 215-219. <https://doi.org/10.1080/02772249909358838>.

Register K (2000) Cigarette butts as litter-toxic as well as ugly. *Underwater Naturalist*, 25(2), 23-29.

Robinson DL (2005) Air pollution in Australia: review of costs, sources and potential solutions. Health Promot J Austr 16(3): 213-220. <https://doi.org/10.1071/he05213>

Savino JF, Tanabe LL (1989) Sublethal effects of phenanthrene, nicotine, and pinane on *Daphnia pulex*. Bull Environ Contam Toxicol 42(5): 778-784. <https://doi.org/10.1007/BF01700403>.

Sebiawu GE, Mensah NJ, Ayiah-Mensah F (2014) Analysis of heavy metals content of tobacco and cigarettes sold in Wa Municipality of Upper West Region, Ghana. Chem Process Eng Res 25: 24-33.

Slaughter E, Gersberg RM, Watanabe K, Rudolph J, Stransky C, Novotny TE (2011) Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish. Tob Control, 20(Suppl 1): i25-i29. <http://dx.doi.org/10.1136/tc.2010.040170>

Talhout R, Schulz T, Florek E, Van Benthem J, Wester P, Opperhuizen A (2011) Hazardous compounds in tobacco smoke. Int J Environ Res Public Health 8(2): 613-628. <https://doi.org/10.3390/ijerph8020613>

Zulfiqar S, Shabbir S, Ishaq M, Shaukat MS, Sarwar MI (2006) Metal distribution in Pakistani and foreign brands of cigarette ash. Bull Environ Contam Toxicol 77(5): 679-686. <https://doi.org/10.1007/s00128-006-1116-6>.

Figures

Figure 1

Schematic diagram of samples (direct and leachate) used for the present study

Figure 2

Artificial smoking of cigarettes

Figure 3

Levels of heavy metals present in the expensive brand.

Figure 4

Levels of heavy metals present in the moderate brand.

Figure 5

Levels of heavy metals present in the cheaper brand.

Figure 6

Level of heavy metals in different leachate samples of the expensive brand

Figure 7

Level of heavy metals in different leachate samples of the moderate brand

Figure 8

Level of heavy metals in different leachate samples of the cheaper brand

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [MariaetalTableEnvironProcess.xlsx](#)