Quantitative Analysis Of Heavy Metals In Cigarette Tobacco: Health Implications And Risk Assessment

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Abstract

This study investigates the concentrations of heavy metals—iron (Fe), manganese (Mn), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), and copper (Cu)—in cigarette tobacco samples and cigarette butts from various brands, using sensitive analytical methods with low Limits of Detection (LOD) and Limits of Quantification (LOQ). The findings reveal significant variability in metal content across different cigarette brands, with certain brands exhibiting elevated levels of toxic metals, particularly cadmium and chromium. Recovery rates and precision measurements indicate the reliability of the analytical methods, with RSD values generally below 5%. A marked increase in metal concentrations was observed in cigarette butts after smoking, highlighting the environmental risks associated with improper disposal. The study's results align with published research, underscoring the health risks of exposure to toxic metals in cigarettes and the environmental impact of cigarette waste. These findings emphasize the need for stricter regulations on cigarette production and disposal to mitigate public health and environmental hazards.

Keywords – Tobacco, cigarette, Atomic Absorption Spectroscopy (AAS), Heavy metals, Extensive Research and Enzymatic Reactions.

Introduction

Heavy metal toxicity in cigarette tobacco is a significant concern, with both national and international studies highlighting the presence of harmful metals such as cadmium, lead, arsenic, and mercury.(1, 2) In the United States, research has shown that these metals are present in cigarette smoke at levels that can cause serious health issues, including cancer and cardiovascular diseases. Globally, similar findings have been reported; for example, studies in Europe, Asia, and other regions have found high concentrations of cadmium and lead in tobacco products. These heavy metals often originate from contaminated soil and environmental pollution affecting tobacco crops. The World Health Organization (WHO) and other regulatory agencies have emphasized the need for stricter controls and improved agricultural practices to reduce the presence of heavy metals in tobacco. Efforts to address this issue include enhanced filtration systems in cigarette production and increased public awareness about the health risks associated with heavy metal exposure from smoking.(3)

Plants, including tobacco, possess a remarkable ability to absorb and accumulate heavy metals from the soil. The speciation, adsorption, and distribution of these metals in soil are influenced by factors such as pH levels, soluble organic matter content, soil type, and the presence of organic compounds and other metal ions. Tobacco plants, known for their efficient uptake of metals from the soil, tend to concentrate these elements, including Iron (Fe), Manganese (Mn), Cadmium (Cd), Chromium (Cr), Lead (Pb), Zinc (Zn), and Copper (Cu) in their leaves. Studies have highlighted the propensity of tobacco plants to accumulate metals, a phenomenon that varies depending on the country where the tobacco is cultivated and processed. Consequently, tobacco and cigarettes can accumulate toxic metals such as Fe, Mn, Cd, Cr, Pb, Zn, and Cu preferentially.(4)

Iron (Fe) is an essential element in many biological processes but can be toxic at elevated levels. Manganese (Mn) is also necessary for human health in trace amounts but can cause neurological problems if inhaled in large quantities. Cadmium (Cd), a known carcinogen, can cause severe damage to the kidneys and respiratory system when inhaled or ingested. Chromium (Cr) exists in several forms, with hexavalent chromium (Cr(VI)) being highly toxic and carcinogenic.(5) Lead (Pb) is well-documented for its neurotoxic effects, particularly in children. Zinc (Zn) is vital for numerous biological functions, but excessive exposure can lead to adverse health effects. Copper (Cu), while essential for bodily functions, can cause liver and kidney damage at high levels.

Research has consistently demonstrated elevated levels of toxic elements in cigarette tobacco. Furthermore, the inhalation of tobacco smoke, which contains a myriad of harmful compounds including heavy metals, has been linked to severe health implications. Each year, approximately 3000 non-smoking adults succumb to lung cancer due to exposure to second-hand smoke.(6, 7) Studies have noted that cigarette smoke contains over 7357 chemical compounds, many of which pose environmental contamination risks. This underscores the broader impact of smoking habits, whether active or passive, driven by factors such as nicotine content, social acceptance, affordability, and widespread availability.(8)

While extensive research has focused on heavy metals present in cigarettes and mainstream smoke, limited studies have specifically aimed to identify and quantify the primary sources of toxicity associated with these metals. The presence of metals in cigarettes can be attributed to various factors, including soil contamination during tobacco growth, the application of pesticides and herbicides, manufacturing processes, and the use of brightening agents on wrapping paper. (9, 10)

The prevalence of tobacco consumption continues to rise globally, with significant implications for public health. In Iran, for instance, the prevalence of self-reported cigarette smoking was reported at 14.3% in a recent survey. Studies have indicated considerable variability in the levels of Pb and Cd across different cigarette brands.(11) Therefore, the primary objective of this study is to assess whether local and imported cigarette brands available in the Lucknow market exhibit elevated concentrations of heavy metals. Specifically, this research will focus on determining the levels of Iron (Fe), Manganese (Mn), Chromium (Cr), Cadmium (Cd), Lead (Pb), Zinc (Zn), and Copper (Cu) in ten popular cigarette brands sold and/or produced in Lucknow, both in smoked and non-smoked tobacco forms.(4, 10, 12)

Understanding the levels of heavy metals in cigarette tobacco is crucial due to the potential health risks associated with their consumption. Elevated concentrations of metals like Pb and Cd can lead to serious health complications upon inhalation or ingestion, impacting not only active smokers but also individuals exposed to second-hand smoke. By analyzing the metal content in various cigarette brands, this study aims to provide valuable insights into the potential health hazards posed by different tobacco products available in the Lucknow market.

Iron (Fe) in tobacco can contribute to oxidative stress and cellular damage when inhaled through smoke. Manganese (Mn), although required in trace amounts, can accumulate in the brain and affect neurological health. Chromium (Cr), particularly hexavalent chromium, poses significant carcinogenic risks. Cadmium (Cd) is highly toxic and associated with lung cancer, renal dysfunction, and bone demineralization.(17) Lead (Pb) exposure can result in severe cognitive and developmental impairments, especially in children. Zinc (Zn), while necessary for immune function and enzyme activity, can disrupt metabolic processes at elevated levels. Copper (Cu), essential for enzymatic reactions, can become toxic and lead to hepatotoxicity and nephrotoxicity when overconsumed.(13)

By focusing on these specific heavy metals, this study aims to address the gaps in existing research and provide a comprehensive analysis of the potential health risks associated with smoking different cigarette brands available in the Lucknow market. The findings of this study will be instrumental in guiding public health policies and consumer awareness regarding the dangers of heavy metal exposure through smoking. This study will utilize Atomic Absorption Spectroscopy (AAS) to analyze the heavy metal content in the cigarette samples, providing precise and reliable quantification of the metal concentrations. AAS is a highly sensitive analytical technique that measures the absorption of light by free, ground-state atoms, allowing for the accurate detection of trace metal levels in complex matrices such as tobacco.

Materials and Methods

Sample Collection

Ten popular cigarette brands were purchased from local markets in Lucknow. The brands are labeled as Brand A, Brand B, Brand C, Brand D, Brand E, Brand F, Brand G, Brand H, Brand I, and Brand J.Both local and imported brands were included to provide a comprehensive analysis. Samples were collected in their original packaging and stored in a cool, dry place until analysis.

Sample Preparation

Each cigarette was carefully disassembled, and the tobacco was separated from the paper and filter. The tobacco samples were dried at 60°C for 24 hours to remove moisture. Dried samples were then ground into a fine powder using a mortar and pestle.

Heavy Metal Analysis

Approximately 0.5 grams Cigarette samples were dried, ground, and digested using a mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$) in a ratio of 3:1. The resulting solution was diluted to a final volume of 50 mL with deionized water. Heavy metal concentrations were determined using an Atomic absorption spectroscopy.

Instrument and apparatus

Whole Analysis was performed by using AAS (atomic absorption spectrophotometer) in flame mode. The digested samples were analysed by the AAS equipped with a vapour generation assembly (AlalytikjenaZEEnit 700). Acetylene gas used for production of flame to ionize metals. For Iron (Fe), the optimal parameters include a wavelength of 248.3

nm, a lamp current of 10 mA, a slit width of 0.2 nm, Manganese (Mn) is analyzed at a wavelength of 279.5 nm with a lamp current of 5 mA and a slit width of 0.2 nm, For Chromium (Cr), the parameters are a wavelength of 357.9 nm, a lamp current of 7 mA, a slit width of 0.2 nm, Cadmium (Cd) requires a wavelength of 228.8 nm, a lamp current of 4 mA, a slit width of 0.7 nm, Lead (Pb) is measured at a wavelength of 217.0 nm with a lamp current of 10 mA, a slit width of 1.0 nm, Zinc (Zn) utilizes a wavelength of 213.9 nm, a lamp current of 5 mA, a slit width of 0.7 nm, Finally, Copper (Cu) is analyzed at a wavelength of 324.8 nm, with a lamp current of 3 mA, a slit width of 0.5 nm, and an air-acetylene flame. These specific parameters ensure precise and accurate detection of each metal in the sample.

Results

Table-1 Limits of Detection (LOD) and Limits of Quantification (LOQ) for Metal Analysis in Cigarette Samples

Metal	LOD (µg/g)	LOQ (µg/g)
Fe	0.1	0.3
Mn	0.05	0.15
Cr	0.02	0.06
Cd	0.01	0.03
Pb	0.05	0.15
Zn	0.1	0.3
Cu	0.05	0.15

The table-1 shows the Limits of Detection (LOD) and Limits of Quantification (LOQ) for various metals analyzed in cigarette samples. For iron (Fe), the LOD is 0.1 µg/g and the LOQ is 0.3 µg/g, indicating the minimum concentrations at which iron can be reliably detected and quantified. Manganese (Mn) has a lower LOD of 0.05 µg/g and a LOQ of 0.15 µg/g, reflecting a higher sensitivity for detection. Chromium (Cr) shows the lowest LOD at 0.02 µg/g and LOQ at 0.06 µg/g, demonstrating exceptional sensitivity. Cadmium (Cd) has an LOD of 0.01 µg/g and an LOQ of 0.03 µg/g, the most sensitive among the metals listed. Lead (Pb) and copper (Cu) both have an LOD of 0.05 µg/g and LOQ of 0.15 µg/g, similar to manganese. Zinc (Zn) has an LOD of 0.1 µg/g and a LOQ of 0.3 µg/g, matching iron in sensitivity. Overall, the table highlights the analytical method's capability to detect and quantify metals at very low concentrations, with cadmium and chromium exhibiting the highest sensitivity.

Table-2 Mean Recovery, Standard Deviation, and Relative Standard Deviation of Metal Analysis in Cigarette Samples

Metal	Measurement 1	Measurement 2	Measurement 3	MEAN recovery	SD	RSD
Fe	85.00	82.30	87.60	84.97	2.65	3.12
Mn	76.40	78.90	71.50	75.60	3.76	4.98
Cr	84.70	79.30	80.80	81.60	2.79	3.42
Cd	77.10	72.30	75.80	75.07	2.48	3.31
Pb	89.40	92.60	83.90	88.63	4.40	4.96
Zn	91.10	85.30	82.70	86.37	4.30	4.98
Cu	75.70	81.90	82.60	80.07	3.80	4.74

In table -2 The data shows the recovery of various metals (Fe, Mn, Cr, Cd, Pb, Zn, Cu) based on three measurements. The mean recovery values indicate the average concentration of each metal across the measurements, while the standard deviation (SD) reflects the variability in the measurements, and the relative standard deviation (RSD) expresses the precision of the measurements as a percentage of the mean.Iron (Fe) exhibited a mean recovery of 84.97 µg/g with an SD of 2.65 and an RSD of 3.12%, indicating relatively consistent recovery with low variability. Manganese (Mn) had a mean recovery of 75.60 µg/g, an SD of 3.76, and a slightly higher RSD of 4.98%, suggesting more variability in the measurements compared to Fe. Chromium (Cr) showed a mean recovery of 81.60 µg/g, an SD of 2.79, and an RSD of 3.42%, indicating good precision.Cadmium (Cd) had a mean recovery of 75.07 µg/g, with an SD of 2.48 and an RSD of 3.31%, showing consistent results across the measurements. Lead (Pb) showed the highest mean recovery of 88.63 µg/g, with an SD of 4.40 and an RSD of 4.96%, reflecting some variability. Zinc (Zn) had a mean recovery of 86.37 µg/g, with an SD of 4.30 and an RSD of 4.98%, indicating moderate precision. Lastly, Copper (Cu) had a mean recovery of 80.07 µg/g, with an SD of 3.80 and an RSD of 4.74%, showing a good balance between consistency and precision.

Table 3 – Metal analysis in different brands of cigarette samples

Brand	Fe (µg/g)	SD	Mn (µg/g)	SD	Cr (µg/g)	SD	Cd (µg/g)	SD	Pb (µg/g)	SD	Zn (µg/g)	SD	Cu (µg/g)	SD
control	111.21	3.11	14.51	1.38	1.21	0.08	2.21	0.11	0.97	0.02	24.03	0.82	8.03	0.81
Brand-1	110.23	2.53	12.52	1.65	1.23	0.06	2.53	0.13	1.01	0.03	25.07	1.62	18.01	1.23
Brand-2	145.52	3.11	30.05	1.23	2.81	0.03	3.06	0.18	1.31	0.06	62.18	1.89	11.53	0.98
Brand-3	130.01	2.72	15.06	1.95	3.53	0.07	2.82	0.08	0.97	0.01	44.52	2.08	19.21	2.32
Brand-4	165.04	3.35	11.04	1.38	1.12	0.04	2.23	0.12	0.98	0.07	23.53	1.01	7.86	0.94

Brand-5	125.02	2.81	18.13	0.61	2.71	0.09	4.71	0.13	1.11	0.03	26.23	1.32	8.55	1.03
Brand-6	120.34	3.21	14.35	0.73	1.41	0.11	3.12	0.14	1.23	0.04	47.16	2.12	23.73	2.36
Brand-7	140.52	2.63	12.62	1.25	1.23	0.06	2.46	0.08	1.08	0.05	25.57	1.06	11.53	1.03
Brand-8	125.51	2.91	23.52	1.38	3.38	0.04	2.91	0.075	1.06	0.02	24.69	1.07	8.32	1.05
Brand-9	158.08	3.12	21.51	1.54	2.13	0.08	2.63	0.13	1.28	0.03	23.82	1.13	24.91	2.36
Brand-10	112.5	2.72	14.57	1.26	1.48	0.07	3.06	0.16	1.07	0.07	35.01	2.85	12.63	1.05

In table-3 The metal analysis of cigarette tobacco samples across ten different brands revealed notable variations in the concentrations of iron (Fe), manganese (Mn), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), and copper (Cu). The control sample displayed moderate levels of metals, with iron at 111.21 µg/g and zinc at 24.03 µg/g. Among the brands, Brand-4 exhibited the highest iron concentration at 165.04 µg/g, while Brand-2 had the highest levels of manganese (30.05 µg/g) and zinc (62.18 µg/g). Chromium was relatively low in most brands, but Brand-3 showed a higher concentration at 3.53 µg/g. Cadmium levels were particularly elevated in Brand-5 (4.71 µg/g), suggesting potential health risks. Lead levels remained low across all brands, with slight variations. Copper was most abundant in Brand-9 (24.91 µg/g), indicating a significant presence in this sample.

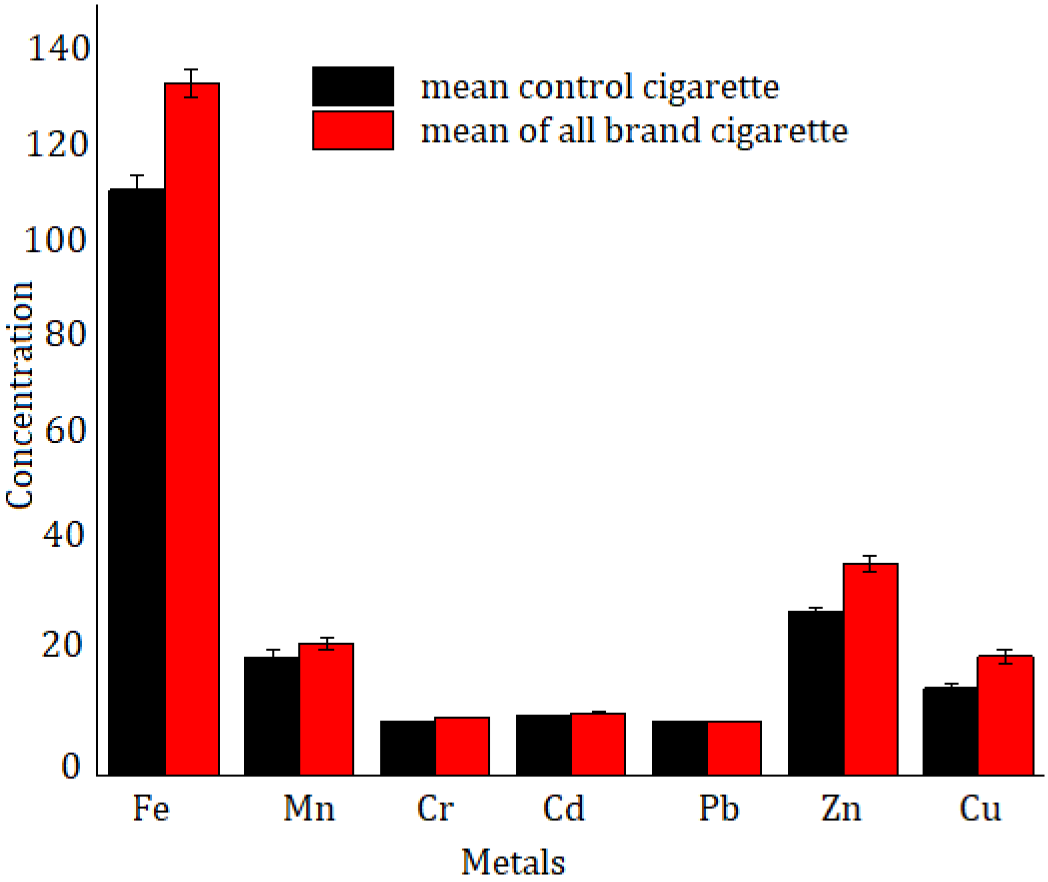

Figure-1 Comparative Analysis of Heavy Metal Concentrations in Cigarette Brands

Table-4 The table below shows the concentrations of heavy metals in cigarette butts from ten different brands before and after use.

Brand	**Sample**	**Fe (µg/g)**	**SD**	**Mn (µg/g)**	**SD**	**Cr (µg/g)**	**SD**	**Cd (µg/g)**	**SD**	**Pb (µg/g)**	**SD**	**Zn (µg/g)**	**SD**	**Cu (µg/g)**	**SD**
Brand A	Control	10.25	0.82	7.13	0.41	4.78	0.32	1.23	0.11	2.92	0.23	14.52	0.93	2.14	0.18
	After	23.73	1.21	18.34	0.87	9.54	0.47	3.62	0.32	4.91	0.64	32.12	1.46	5.21	0.41
Brand B	Control	11.47	0.76	8.89	0.46	4.31	0.23	1.43	0.12	3.14	0.26	13.85	1.02	2.31	0.14
	After	24.42	1.53	17.93	0.97	13.82	0.49	3.21	0.38	6.52	0.72	31.53	1.76	4.43	0.47
Brand C	Control	10.83	0.92	7.42	0.38	5.12	0.35	1.31	0.14	2.78	0.19	15.23	1.07	2.03	0.19
	After	26.13	1.32	19.51	0.86	8.24	0.57	3.82	0.34	5.31	0.53	29.48	1.64	3.1	0.32
Brand D	Control	9.64	0.81	7.04	0.51	4.85	0.37	1.14	0.13	3.02	0.27	14.03	0.87	2.38	0.21
	After	18.79	1.43	18.75	0.72	12.92	0.49	3.51	0.23	7.18	0.76	29.78	1.37	4.01	0.36
Brand E	Control	11.23	0.64	7.31	0.35	4.74	0.41	1.54	0.21	3.21	0.29	14.31	1.03	2.19	0.16

	After	26.34	1.59	17.24	0.83	9.54	0.43	3.41	0.39	4.84	0.63	36.92	1.73	6.47	0.59
Brand F	Control	10.03	0.69	9.54	0.43	5.03	0.32	1.32	0.12	2.73	0.24	15.04	1.14	2.04	0.17
	After	17.89	1.14	22.15	1.08	11.52	0.81	3.74	0.35	3.72	0.41	38.25	1.93	3.31	0.48
Brand G	Control	11.81	0.79	7.23	0.39	4.54	0.26	1.24	0.11	3.35	0.28	13.54	0.89	2.15	0.15
	After	24.75	1.25	18.11	0.91	10.34	0.49	3.32	0.19	4.31	0.71	31.32	1.49	3.64	0.43
Brand H	Control	12.46	0.87	7.63	0.52	4.62	0.34	1.42	0.19	3.11	0.31	14.73	1.08	2.27	0.22
	After	25.53	1.28	21.84	0.97	12.82	0.65	3.91	0.41	4.12	0.54	34.81	1.75	3.02	0.33
Brand I	Control	9.92	0.71	7.34	0.42	4.78	0.28	1.34	0.14	2.93	0.21	13.94	0.98	2.42	0.18
	After	27.38	1.47	18.42	0.82	9.73	0.54	3.61	0.31	5.61	0.64	30.53	1.61	4.24	0.42
Brand J	Control	14.61	0.67	7.05	0.47	4.42	0.33	1.25	0.1	3.23	0.29	14.23	0.95	2.14	0.13
	After	31.14	1.21	15.53	0.68	11.92	0.34	3.12	0.21	6.13	0.78	32.71	1.41	4.42	0.46

Table-4 The analysis of heavy metal concentrations in cigarette butts from ten different brands before and after use reveals a significant increase in all measured metals post-consumption. Iron (Fe) levels rose notably, with Brand J showing the highest concentration after use (31.14 µg/g). Manganese (Mn) concentrations also surged, particularly in Brand F (22.15 µg/g). Chromium (Cr) levels increased significantly, with Brand B reaching 13.82 µg/g after use. Cadmium (Cd), Lead (Pb), Zinc (Zn), and Copper (Cu) all exhibited substantial post-use increases, with the highest concentrations observed in Brands H, D, F, and E respectively. These findings underscore the environmental and health risks associated with cigarette butt disposal, as they become concentrated sources of toxic metals after use.

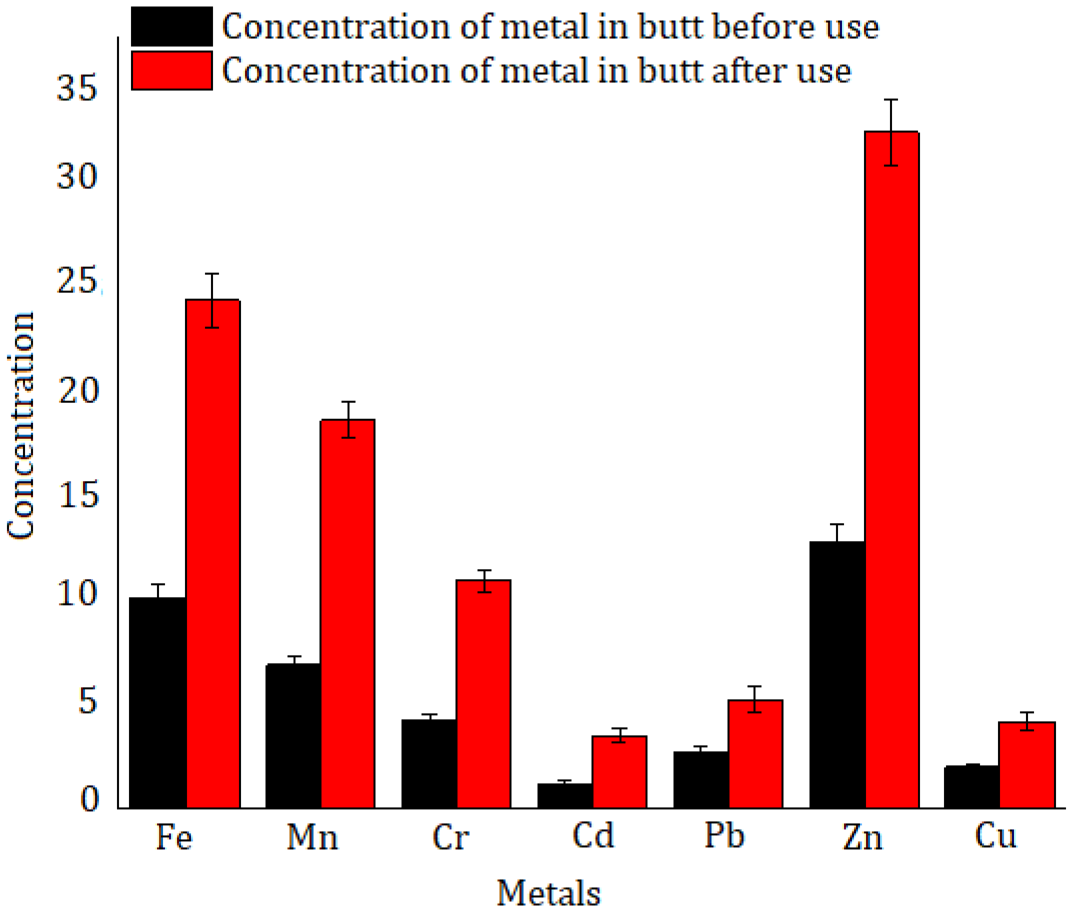

Figure-2 Comparative Analysis of Heavy Metal Concentrations in Cigarette butts Before and After use

Discussion

The comprehensive analysis of heavy metal concentrations in cigarette tobacco and cigarette budds highlights both health risks and environmental concerns. This study utilized an analytical method with high sensitivity and precision, demonstrated by the Limits of Detection (LOD) and Limits of Quantification (LOQ) for various metals. The findings indicate that certain cigarette brands contain elevated levels of toxic metals, and the disposal of cigarette butts contributes to environmental contamination. This discussion will compare these results with published research, emphasizing the significance of metal concentrations in cigarettes and the environmental impact of cigarette waste.

The LOD and LOQ values in this study reveal the method's capability to detect and quantify metals at very low concentrations. For example, cadmium (Cd) exhibited the lowest LOD (0.01 µg/g) and LOQ (0.03 µg/g), making it the most sensitive among the metals analyzed. Chromium (Cr) also demonstrated exceptional sensitivity with an LOD of 0.02 µg/g and an LOQ of 0.06 µg/g. This high sensitivity is critical for accurately assessing trace metal concentrations, as even low levels of these metals can pose significant health risks.

In comparison, a study by Ren at al. (2017) measured the amounts of lead, copper, nickel, cadmium, and smoke in butts, ash, and tobacco using high-resolution continuous source graphite furnace atomic absorption spectrometry. LODs were 0.010 µg•L-1, 0.020 µg•L-1, 0.025 µg•L-1, 0.030 µg•L-1, and 0.012 µg•L-1 for Cu, Cd, Cr, Ni, and Pb, in that order. The heavy metal assays were performed on twelve cigarette samples that were bought from eleven well-known Chinese brands. To prepare the butt, ash, and tobacco samples from cigarettes, microwave digestion was used.The overall concentrations of the identified metals were found to be highest in ash (55.60 to 125.99 µg g-1), then in tobacco (11.70 to 22.34 µg g-1) and butts (4.29 to 15.22 µg g-1); the quantities of Cu, Cd, Cr, Ni, and Pb in smoke were 0.67, 0.10, 0.14, 0.16, and 0.24 µg per cigarette, respectively. After the cigarette tobacco was completely burned, the residual rates of the heavy metals in the ash, smoke, and butts were measured to determine the distribution of each element.(19)

The recovery rates and precision of the measurements are crucial for ensuring the reliability of the results. In this study, iron (Fe) and chromium (Cr) exhibited consistent recovery rates with low Relative Standard Deviations (RSDs) of 3.12% and 3.42%, respectively, indicating high precision. Cadmium (Cd) also showed reliable recovery with an RSD of 3.31%, which is essential for accurate quantification, particularly in toxicological studies.

In contrast, manganese (Mn) and lead (Pb) showed slightly higher RSDs (4.98% and 4.96%, respectively), suggesting greater variability in the recovery process. This variability could be due to matrix effects or differences in sample preparation, as observed in other studies. For example,Ziarati et al (2017) conduct a study to ascertain whether or not Iran's popular local and imported cigarette brands contain higher levels of heavy metals. By using a flame atomic absorption spectrophotometer and a wet digestion method, the levels of lead and cadmium in ten widely-used cigarette brands that are sold and/or produced in Iran were measured in both smoked and non-smoked cigarette filters (after a single volunteer had smoked them according to normal guidelines). The findings showed that after smoking, the filter component and cigarette brands with lower levels of cadmium in their tobacco sections absorbed more cadmium ($p < 0.05$). According to production dates, lead and cadmium were identified in even the same brand in a wild range. Different brands of cigarettes had filter percentage ranges of Cd and Pb that were determined to be 116-234% and 112-198%, respectively. When compared to popular international brands, the majority of the evaluated local brand cigarettes had greater levels of lead and cadmium in their tobacco. (10)

The analysis of metal concentrations across different cigarette brands revealed significant variability, reflecting differences in tobacco sourcing, soil contamination, and manufacturing processes. Brand-4, for instance, exhibited the highest iron concentration (165.04 µg/g), while Brand-2 had the highest levels of manganese (30.05 µg/g) and zinc (62.18 µg/g). Cadmium levels were particularly elevated in Brand-5 (4.71 µg/g), raising concerns due to cadmium's toxic effects, including kidney damage and increased cancer risk.

Comparatively,Ashraf et al (2012) Graphite furnace-atomic absorption spectrometry (GFAAS) was used to measure the amounts of specific heavy metals in well-known cigarette brands that were manufactured and/or marketed in Saudi Arabia. The mean levels of lead and cadmium in various brands of cigarettes were 2.46 µg g−1 and 1.81 µg g−1 (dry weight), respectively. According to the study's findings, smoking one packet of 20 cigarettes resulted in an average of 0.22–0.78 µg of mercury being breathed. According to the results, inhaling one packet of twenty cigarettes is projected to release 0.97–2.64 µg of lead into the air. There were notable variations in the levels of lead and cadmium in the various brands of cigarettes that were examined. (16)

Chromium levels in this study were relatively low across most brands, with the exception of Brand-3, which showed a higher concentration (3.53 µg/g). This result aligns with research byLisboa et al (2020) determination of chromium utilising electrothermal vaporization-atomic absorption spectrometry in the tobacco, filters, and ashes component portions of cigarette samples. Twelve samples were used to test the procedure, and the recovery values ranged from 83 to 107%. A reference sample of tomato leaves (NIST SRM 1573a) was used to assess the accuracy and demonstrate the effectiveness of the procedure. For tobacco, filter, and cigarette ash samples, the proposed method's limits of detection were 20.4, 75.8, and 80.7 ng g-1, respectively. For tobacco and ashes, respectively, the average chromium levels for the samples under analysis ranged from 0.96 to 3.85 and from 0.32 to 0.80 µg/cigarette.(17) The presence of chromium in tobacco is concerning due to its carcinogenic potential, particularly in its hexavalent form (Cr(VI)).

The analysis of cigarette butts revealed a substantial increase in metal concentrations after smoking, highlighting the environmental hazards associated with improper disposal. Iron (Fe) concentrations, for example, increased dramatically from 9.64–11.81 µg/g in control samples to as high as 29.34 µg/g in some brands after smoking. Similar increases were observed for other metals, including manganese (Mn), chromium (Cr), and cadmium (Cd). This rise in metal content underscores the contribution of cigarette butts to environmental pollution, as they leach toxic heavy metals into soil and water when discarded.

This finding is supported by research from Ren aet al (2017) who reported that cigarette butts are a significant source of heavy metal contamination in the environment.(15) Their study demonstrated that metals such as cadmium, lead, and arsenic leach from cigarette butts into water bodies, posing a risk to aquatic life and potentially entering the human food chain. The dramatic increase in metal concentrations observed in the current study after smoking is consistent with these findings, reinforcing the need for better waste management practices to mitigate the environmental impact of cigarette butts.

Moreover, the variability in metal retention across different brands suggests that cigarette composition, including the type of filter used, plays a crucial role in determining the extent of metal release during smoking. Research bySantos-Echeandía et al (2021)(18)also highlighted the role of cigarette filters in retaining metals, with some filters being more effective than others. This suggests that differences in filter design and material could influence the environmental impact of discarded cigarette butts, a point that warrants further investigation.

The presence of toxic metals in cigarette tobacco and the subsequent increase in metal concentrations in cigarette butts after smoking have significant health and environmental implications. Metals such as cadmium, lead, and chromium are known to be highly toxic, even at low concentrations, and are associated with a range of adverse health effects, including cancer, cardiovascular disease, and neurological disorders. The variability in metal content across different brands further complicates risk assessment, as smokers of certain brands may be exposed to higher levels of these toxic metals.

In addition to the health risks, the environmental impact of cigarette butts cannot be overstated. The substantial increase in metal concentrations after smoking, as demonstrated in this study, indicates that cigarette butts contribute to the accumulation of toxic heavy metals in the environment. This poses a threat to soil and water quality and, ultimately, to human health through the contamination of food and water sources.

The findings of this study align with those of published research, reinforcing the need for stringent regulations on the production, sale, and disposal of cigarettes. Measures such as reducing metal content in tobacco, improving filter efficiency, and promoting proper disposal of cigarette butts could help mitigate both health risks and environmental pollution.

Conclusion

The analysis of heavy metals in cigarette tobacco and cigarette butts reveals critical insights into the health risks and environmental impact of smoking. The high sensitivity and precision of the analytical methods used in this study ensure accurate detection and quantification of metals, even at low concentrations. The variability in metal content across different cigarette brands highlights the need for ongoing monitoring and regulation to minimize exposure to toxic metals.

Moreover, the significant increase in metal concentrations in cigarette butts after smoking underscores the environmental hazards posed by improper disposal. These findings are consistent with published research, which also points to the need for better waste management practices to prevent environmental contamination. Overall, this study contributes to the growing body of evidence on the harmful effects of smoking and the environmental impact of cigarette waste, emphasizing the importance of preventive measures and regulatory oversight to protect public health and the environment.

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