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RELEASE OF POTENTIALLY TOXIC METALS FROM CIGARETTE BUTTS IN SIMULATED ENVIRONMENTAL MEDIA

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Introduction

Cigarette butts (CBs) are one of the most widespread forms of litter worldwide, with approximately 4.5 trillion discarded annually. Their improper disposal represents an important environmental concern because CBs can release various toxic compounds, including heavy metals, polycyclic aromatic hydrocarbons (PAHs), nicotine, and other organic pollutants. In addition, cigarette filters are mainly composed of cellulose acetate and can contribute to microplastic pollution. When exposed to rainwater or soil moisture, CBs may release contaminants through leaching, potentially affecting soil and water quality and posing risks to terrestrial and aquatic ecosystems. Leaching tests are therefore useful tools for assessing the mobility and environmental release of contaminants from cigarette butt waste. Despite growing attention to cigarette-related waste, information on the mobility of metals under different environmental conditions remains limited. Therefore, this study aimed to evaluate the leaching behavior of selected metals from conventional cigarette butts and electronic cigarette waste using extraction media designed to simulate different environmental conditions. The influence of pH and leaching solution composition on metal release was investigated to assess their potential mobility and environmental availability.

Materials and methods

Seven cigarette brands were included in the study, five of which were conventional cigarettes consumed through combustion (S2, S3, S5, S6 and S7) and two were heated tobacco products (S1 and S4). Five leaching solutions were selected to mimic a range of physical-chemical conditions that may occur in environmental matrices: (A) ultrapure water; (B) 0.4 M $MgCl_2$ at pH 6.5; (C) NaOH solution at pH 8; (D) CH_3COOH solution at pH 2.5; and (E) CH_3COOH/ CH_3COONa buffer at pH 5. The report for leaching test was 1:20 (mass: volume).

An aliquot of 25 mL of the extract was taken for digestion with aqua regia (2 mL HNO3 and 6 mL HCl). After digestion, the samples were filtered and prepared for analysis. The metal content of the leachate samples was analysed using an ICP-OES PerkinElmer Avio 500 equipment. Calibration curves were constructed for each element, with a correlation coefficient R^2 higher than 0.995, ensuring precise quantification of metal concentrations.

Results and conclusions

Arsenic (As), lead (Pb), and antimony (Sb) were not detected in any of the investigated leachates. Selenium (Se) was found at relatively low concentrations, ranging from 1.42 to 2.90 mg kg^{-1} dry weight (d.w.). Cadmium (Cd) was detected in all samples leached with $MgCl_2$, at concentrations between 0.07 and 0.15 mg kg^{-1} d.w., and in the CH_3COOH medium, where values ranged from 0.07 to 0.17 mg kg^{-1} d.w., indicating a higher mobility of Cd under these extraction conditions. Aluminium (Al) was the predominant element released from both conventional and electronic cigarette waste and was detected in all leaching media. For conventional cigarette butts, Al concentrations ranged from 15.5 to 45.9 mg kg^{-1} d.w. in ultrapure water and $MgCl_2$, whereas higher values, ranging from 35.9 to 274 mg kg^{-1} d.w., were obtained in the other leaching media. In electronic cigarette samples, Al concentrations generally ranged from 9.56 to 232 mg kg^{-1} d.w. A significantly higher concentration of 4015 mg kg^{-1} d.w. was recorded for one sample leached with NaOH, suggesting that alkaline conditions may substantially enhance Al release from specific electronic cigarette components.

Manganese (Mn) was the second most abundant element released under the investigated conditions. Concentrations ranged from 14.3 to 51.5 mg kg^{-1} d.w. in $MgCl_2$, CH_3COOH, and CH_3COOH / CH_3CONa media, compared with 6.07–29.4 mg kg^{-1} d.w. in ultrapure water and 1.62–18.3 mg kg^{-1} d.w. in NaOH. Iron (Fe) concentrations were generally below 10 mg kg^{-1} d.w. in all leaching media, with the exception of NaOH, where values between 6.05 and 26.3 mg kg^{-1} d.w. were recorded. Copper (Cu) was generally released at considerably lower levels, with most concentrations ranging from 0.20 to 4.16 mg kg^{-1} d.w. regardless of the leaching medium. Higher Cu concentrations were observed for two conventional cigarette butt samples. For S2, values ranged from 16.02 to 29.5 mg kg^{-1} d.w. across all investigated media, whereas S7 showed a concentration of 16.9 mg kg^{-1} d.w. in ultrapure water. The results demonstrate that the release of metals from cigarette waste is strongly dependent on both the element and the physical-chemical characteristics of the surrounding medium. Al and Mn showed the highest overall mobility, while Cd release was particularly associated with $MgCl_2$ and acidic conditions. The pronounced Al release observed in one electronic cigarette sample under alkaline conditions also highlights the influence of product composition on metal leaching behavior. These findings suggest that waste conventional and electronic cigarette products may serve as potential sources of metal contamination when subjected to environmental conditions characterized by varying pH and ionic composition.

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