

GF-AAS Determination of Cadmium in Different Cigarettes and Cigarette Smoke

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In the present work an electrothermal atomic absorption spectrometric method has been used for the determination of cadmium in cigarette constituents and smoke. The concentrations of cadmium in tobacco, tobacco ash and side-stream smoke were 1.3–3.1, 0.12–0.50 and 0.039–0.170 $\mu\text{g/g}$, respectively, for different cigarettes. Cadmium in the mainstream smoke was not detectable. It was, therefore, concluded that passive smokers are at a higher risk of intoxication by cadmium compared to smokers.

Key Words: Cigarette, Smoke, Cadmium determination, GF-AAS.

INTRODUCTION

It is well known that trace metals may play an important role in human metabolism¹ and either an excess or deficiency of certain metals in the organism can lead to biological disorders, which include anemia, some particular forms of cancer and even death^{2,3}. Environmental studies of cadmium as an accumulative toxic metal are increasing recently. Kidney, liver, lungs and pancreas are the main organs of humans for accumulation of cadmium. Cadmium toxicity may be manifested by a variety of syndromes and effects including renal dysfunction, hypertension, hepatic injury, lung damage and teratogenic effects⁴. Cadmium is one of the most hazardous elements to human health. Although the discharge of wastewater containing cadmium to the environment is strictly regulated at present, the large scale use of this metal and metallurgical processes of cadmium containing minerals in the past had brought a certain level of cadmium into our living environment and caused diseases in some areas. Moreover, due to the persistent character of this heavy metal in nature and ecosystems, the released cadmium is still remaining in the environment and keeps on accumulating in the human body *via* the food chain. Thus, the development of a sensitive and accurate method to determine the trace amounts of cadmium in biological and environmental samples has been continuously an important topic in analytical chemistry^{5–8}. Possible sources of toxic metals include food, beverages and living and working environments. For smokers, cigarettes may constitute an additional source of toxic metals. If cadmium is present in cigarettes, it may be inhaled during smoking. Most of the work, concerned with the determination of toxic metals in cigarettes, has been carried out using neutron activation analysis^{9,10}. However, this technique is not the best choice for the determination of cadmium because it does not have easily measurable isotopes. Elements such as As, Be, Cd, Hg, Pb and Tl are known to have toxic effects upon life processes, even at

very low concentration. Therefore the determination of these elements, especially cadmium, in cigarette is necessary and has been done by different methods¹¹. Some of these methods that were used are suitable but instrumentals are not available. In the present work we have developed an electrothermal atomic absorption spectrometry method for determination of cadmium in different Iranian and foreign cigarette constituents and cigarette smoke.

EXPERIMENTAL

All chemical reagents used were of analytical grade. Cadmium sulfate ($\text{CdSO}_4 \cdot 8\text{H}_2\text{O}$) from Merck was dissolved in double distilled water and diluted to 100 mL flask to give 1000 $\mu\text{g/mL}$ Cd^{2+} and standardized by known method¹². For the determination of cadmium, atomic absorption measurements were made on Shimadzu model AA-670 spectrometer equipped with a GF-AAS graphite furnace atomizer, deuterium arc background correction system and auto sample injector model AIU-1. Operation conditions are given in Table-1. The heating program for determination of cadmium in different constituents is shown in Table-2.

TABLE-1
GRAPHITE FURNACE OPERATION CONDITIONS FOR
DETERMINATION OF CADMIUM

Lamp current/mA	4
Wavelength/nm	228.8
Spectral band width/nm	0.3
D ₂ arc background correction	on
Injection volume/ μL	5
Measurement mode	Peak height
Integration time/s	5

TABLE-2
HEATING PROGRAM FOR DETERMINATION OF CADMIUM
IN TOBACCO, ASH AND SMOKE

Sample	Ashing temperature (°C)	Hold times (s)	Atomization temperature (°C)	Hold times (s)
Tobacco	300	20	1500	3
Smoke	150	20	1200	3
Ash	150	20	1300	3

Sampling

(A) **Tobacco:** The tobacco of one packet of cigarette was manually ground in an agate mortar to a powdery texture. The finely ground tobacco was dried in air at approximately 90°C for 12 h and kept in a desiccator before being analyzed. Three 0.2 g portions of the ground, homogenized and dried tobacco sample of each individual cigarette brand were dissolved in 4 mL concentrated nitric acid and diluted to 25 mL in a volumetric flask. Cadmium was then determined by GF-AAS.

(B) **Main-stream smoke:** The main-stream smoke from two cigarettes, randomly selected from each brand was collected. For this purpose cigarettes

were sequentially inserted into the internal glass tubing of the assembly and gentle suction was initiated *via* the lateral arm of the external glass cylinder, by means of a vacuum pump. The smokes of two cigarettes were passed through 14 mL concentrated nitric acid. Then the sample was introduced to a 25 mL volumetric flask and diluted. Then cadmium was determined by GF-AAS.

(C) **Side-stream smoke:** The side-stream smoke from two cigarettes, randomly selected from each brand, was collected. The smokes were then dissolved in 14 mL concentrated nitric acid and introduced into 25 mL volumetric flasks and then cadmium determined by GF-AAS.

(D) **Ash:** Three 0.2 g portions of ground and homogenized ash from each cigarette brand were collected. The samples were digested in 4 mL concentrated nitric acid and diluted in a 25 mL volumetric flask. Then cadmium was determined by GF-AAS.

RESULTS AND DISCUSSION

The graphite furnace heating conditions were optimized with a view to obtain maximum integrated absorbance signals for cadmium in each constituent part of the cigarettes. The drying conditions, with a temperature of 100°C and hold time of 30 s, were common to all matrices. The linear range for determination of cadmium was 0.002–0.03 mg/L. Concentration of cadmium in different constituents has been shown in Table-3.

TABLE-3
CONCENTRATION OF CADMIUM IN TOBACCO, ASH, MAIN-STREAM
AND SIDE-STREAM SMOKE ($\mu\text{g/g}$) IN DIFFERENT BRANDS

Sample	Tobacco	Main-stream smoke	Side-stream smoke	Ash
57	1.30 (± 0.02)	N.D.	0.250 (± 0.030)	0.500 (± 0.009)
Bahman	3.10 (± 0.05)	N.D.	0.170 (± 0.025)	0.250 (± 0.005)
Mond	2.20 (± 0.04)	N.D.	0.039 (± 0.017)	0.120 (± 0.004)
Montana	2.00 (± 0.03)	N.D.	0.037 (± 0.033)	0.120 (± 0.005)
Zar	3.00 (± 0.04)	N.D.	0.050 (± 0.016)	0.250 (± 0.008)

N.D.: Not detected.

Cadmium was determined in various brands of cigarettes of which three are Iranian. The average concentration of cadmium in tobacco of Iranian cigarettes is 2.5 $\mu\text{g/g}$. This value is similar to those reported in two studies^{4, 13} and higher than one study¹⁴. The average concentration of cadmium in ash in Iranian cigarettes is 0.3 $\mu\text{g/g}$. This value is lower than that in Venezuelan cigarettes¹⁵. In the present work cadmium was not detectable in main-stream smoke but Rickert¹³ and Kalaitzoglou¹⁶ determined cadmium in main-stream smoke of Canadian and Greek cigarettes respectively. The average concentration of cadmium in side-stream smoke of Iranian cigarettes is 0.157 $\mu\text{g/g}$. Brand Bahman shows the highest concentration in side-stream smoke (Table-3). The comparison of cadmium concentration in tobacco, side-stream smoke and ash of different cigarettes are shown in Figs. 1–3.

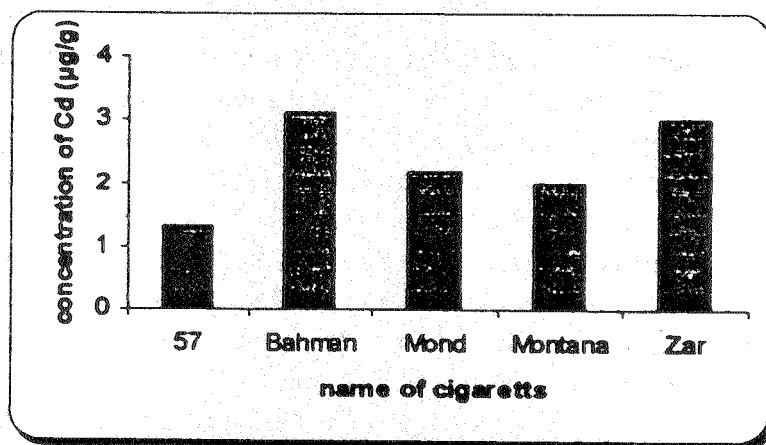


Fig. 1. Concentrations of cadmium in tobacco of different cigarettes

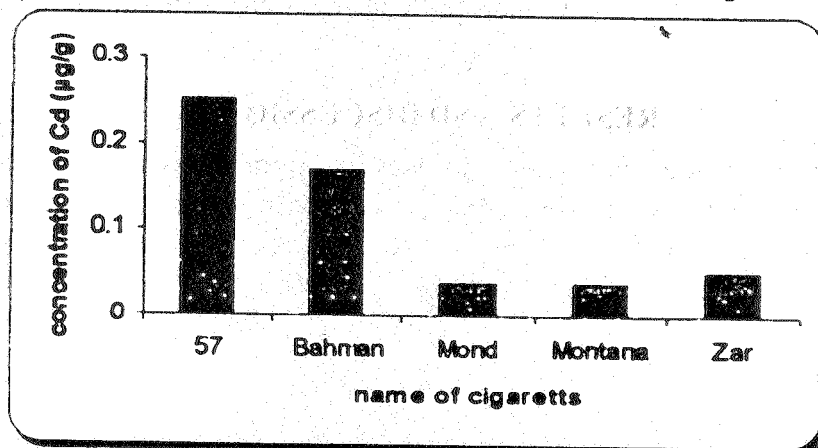


Fig. 2. Concentrations of cadmium in side-stream smoke of different cigarettes

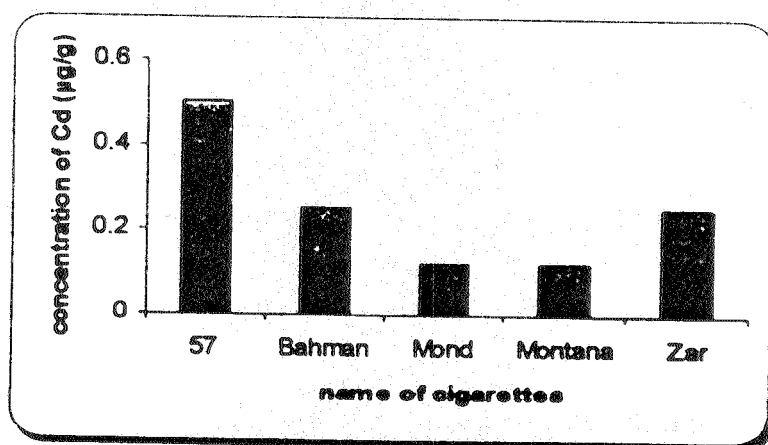


Fig. 3. Concentrations of cadmium in ash in different cigarettes

Conclusion

This work proposed a selective and sensitive GF-AAS for rapid determination of cadmium in the cigarette constituents. The results show that different constituents of cigarette contain different concentrations of the element of interest. Among the different cigarette brands which were selected for this study, there is not a specific one that contains intermediate concentration of cadmium. From the results, it could be concluded that passive smokers are at a higher risk of intoxication by cadmium compared to smokers. The source of trace element in

cigarette tobacco can be traced by soil type, fertilizer composition and application water used for irrigation, storage condition, etc. or to the manufacturing practice, which may be influenced by processing techniques and additives. Thus, speculation on the exact source of the measured element seems to be futile.

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