Heavy metal and polycyclic aromatic hydrocarbons in cigarettes: An analytical assessment

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ABSTRACT

INTRODUCTION Tobacco products contain heavy metals and polycyclic aromatic hydrocarbons (PAHs) that can be released during burning. The aim of this study was to measure the concentrations in tobacco of the heavy metals: Lead (Pb), Cadmium (Cd), Chrome (Cr), and Zinc (Zn); and the amount polycyclic aromatic hydrocarbons (PAHs) in tobacco and tobacco product emissions using Cambridge filter pads under U.S. Federal Trade Commission (FTC) standard conditions.

METHODS In the present analytical study, samples of 25 tobacco brands of different origin were analyzed to determine both heavy metal concentrations utilizing flame atomic absorption spectroscopy (FAAS) and polycyclic aromatic hydrocarbons amounts using gas chromatography (GC).

RESULTS The average concentrations of Pb, Cd, Cr and Zn s were 4.56, 0.39, 3.31 and 1.36 μg/g, respectively. The amount of PAHs in cigarette emissions ranged from 474.17 ng/cigarette to 1060.87 ng/cigarette for tobacco brands labelled C13 and C2, respectively. The order in amount of the PAHs in the smoke of the study tobacco brands was: nap > flu > acpy > phn > fln > pyr > acp > ant > chr > bap > bbf (full names listed in main text).

CONCLUSIONS Tobacco and tobacco product emissions contain significant concentrations of heavy metals and PAHs amounts, respectively.

INTRODUCTION

Tobacco contains more than 6000 toxic compounds that are released during the smoking process[1,2] and they constitute a significant risk for a variety of respiratory and cardiovascular diseases and developing cancers. These compounds include heavy metals such as lead, cadmium, copper, arsenic, and nickel besides polycyclic aromatic hydrocarbons (PAHs), like benzo[a]pyrene, that have been characterized as strong carcinogens for humans[3].

Exposure to heavy metals due to smoking of a single cigarette can be trivial and likely not severely toxic, but their accumulation in the body through exposure over a long period of time (months, years, and decades) depends on clearance rates and constitutes a serious health concern[4,5]. Many heavy metals like Cd, Ni, Pb, and Cr can accumulate in organ tissues after smoking, especially Cd and Pb, which have long half-lives of 10 to 12 years within the human body. Cigarette smoking can be considered as the main access of exposure for Cd, and to a less extent Pb, in the general population[6-9].

PAHs result from incomplete combustion of manmade sources like transportation, energy generation and industrial sectors. Previous researchers have determined 16 compounds of PAHs in mainstream cigarette smoke, 10 of which have significant environmental and health effects, like benzo[a]anthracene and naphthalene[10,11].

The aim of this study was to measure the heavy metal concentrations of tobacco and the amount of PAHs using Cambridge filter pads under U.S. Federal Trade Commission (FTC) standard conditions.

METHODS

In this study, which was conducted in January 2019, in the Environmental Research Center, University of Technology, Baghdad, Iraq, 24 brands of imported cigarettes of seven different origins and one local brand (USA, UK, Korea, Turkey, France, Switzerland, and Iraq) were collected to determine both heavy metal concentrations utilizing flame atomic

absorption spectroscopy (FAAS), and polycyclic aromatic hydrocarbons amounts using gas chromatography (GC).

The investigated heavy metals were lead (Pb), cadmium (Cd), chrome (Cr) and zinc (Zn). The contents of each pack were emptied in the laboratory by removing cigarette papers and filters. Tobacco samples were then pulverized by ceramic mortar and five grams of tobacco powder of each brand sample was added to 25 mL of concentrated HNO_3, then mixed well and put on a hotplate for 3 hours at 120 ^oC[12]. The digested samples were filtered through 0.45 Millipore filter paper and made up to 10 mL using a volumetric flask with deionized water. The heavy metal concentrations were then analyzed using an atomic absorption spectrophotometer (Shimadzu AA-6800 graphite furnace atomic absorption spectrophotometer GFAAS, Japan).

The PAHs were: naphthalene (nap), acenaphthene (acpy), fluorene (flu), acenaphthene (acp), phenanthrene (phn), anthracene (ant), fluoranthene (fln), benzo[a]pyrene (bap), chrysene (chr), benzo[b,k] fluoranthene (bbf), and pyrene (pyr). Cigarette mainstream smoke was collected on Cambridge filter pads under U.S. Federal Trade Commission (FTC) standard conditions with 2- second breath duration, a 35-mL puff volume at a frequency of one puff per minute. The smoke samples were analyzed by gas chromatography (GC) together with a Thermal Energy Analyzer (TEA) (Orion Research, Beverly, MA), as described elsewhere[13].

RESULTS

Heavy metals

Table 1 summarizes the concentrations of the heavy metals for the study tobacco brands. Pb concentrations ranged from 1.24–9.26 µg/g with an average value of 4.56 µg/g. Brand C19 recorded the highest concentration value of Pb while C11 recorded the lowest concentration value with significant differences at p≤0.05. Concentrations of Cd ranged from not detected (ND) in C1 and C20 samples, to the highest value of 1.56 µg/g in C15, with an average value of 0.40 µg/g with significant differences at p≤0.05. The Cr concentration values ranged from ND in C5, C7 and C13 samples to the highest concentration of 6.73 µg/g in the C23, and an average value of 3.31 µg/g, with significant differences at p≤0.05. Finally, concentrations of Zn ranged from 0.17–3.11 µg/g with an average 1.369 µg/g, the highest level in the C21 sample while the lowest level was in the C17 sample, with significant differences at p≤0.05. Generally, the concentrations of the heavy metals varied considerably among the brands.

Polycyclic aromatic hydrocarbon

In this study, 11 PAHs amounts were identified and are listed in Table 2. The results show that the levels (ng/cigarette) of PAHs in emissions ranged: 101–400, 35–198, 10–284, 8.2–87, 17–166, 5.8–86.3, 39–90, 2–22.5, 10.9–27.02, 2.66–8.57 and 21.3–84.8 for nap, acpy, flu, acp, phn, ant, fln, bap, chr, bbf, and pyr, respectively. The nap was present in higher amounts compared to other PAHs in all tobacco samples. The order of the total amount of the PAHs in the smoke of the study tobacco brands was: nap > flu > acpy > phn > fln > pyr > acp > ant > chr > bap > bbf.

Table 1. Heavy metal mean concentrations (µg/g) in 25 tobacco brands

Brands	CFW (g)	Moisture content (%)	Pb	Cd	Cr	Zn	TCHM
C1	0.66	11.31	3.12	ND	1.17	2.25	6.54
C2	0.57	12.43	6.15	0.27	1.27	0.42	8.11
C3	0.61	12.66	3.34	0.16	2.79	0.79	7.07
C4	0.63	11.72	3.42	0.31	1.45	0.78	5.95
C5	0.63	11.92	4.42	0.33	ND	0.89	5.64
C6	0.64	11.11	5.51	0.47	3.01	0.47	9.45
C7	0.62	12.13	4.35	0.33	ND	0.37	5.04
C8	0.61	12.80	3.13	0.17	1.687	1.07	6.05
C9	0.58	12.56	5.17	0.13	1.23	1.08	7.60
C10	0.74	11.24	3.12	0.13	1.96	2.98	8.19
C11	0.63	11.67	1.24	0.20	2.63	1.47	5.54
C12	0.63	12.93	3.15	0.43	1.78	2.11	7.47
C13	0.63	13.43	2.42	0.39	ND	2.01	4.82
C14	0.61	12.45	4.51	0.39	5.63	1.56	12.09
C15	0.62	12.26	5.13	1.56	0.92	0.77	8.38
C16	0.61	12.44	2.93	0.83	2.86	2.11	8.74
C17	0.54	11.38	5.23	0.83	3.12	0.17	9.35
C18	0.66	12.38	3.94	1.01	2.44	0.46	7.84
C19	0.66	11.45	9.26	0.26	2.71	1.72	13.95
C20	0.63	11.88	9.24	ND	7.23	2.47	18.94
C21	0.65	12.45	7.24	0.13	2.17	3.11	12.64
C22	0.66	12.49	5.12	0.30	3.13	2.12	10.66
C23	0.56	12.21	5.18	0.57	6.73	1.01	13.48
C24	0.78	11.38	2.15	0.46	2.23	1.10	5.93
C25	0.63	11.67	5.634	0.54	0.65	0.98	7.80
Min	0.54	11.11	1.24	0.00	0.00	0.17	4.82
Max	0.74	13.43	9.26	1.56	6.73	3.11	18.94
Average	0.63	12.09	4.56	0.40	3.32	1.37	8.69
SD	0.05	0.59	0.00	0.34	1.91	0.82	3.28

CFW: cigarette filler weight. ND: not detected. TCHM: total content of heavy metals.

Table 2. The polycyclic aromatic hydrocarbon (PAHs)* amount (ng/cigarette) in 25 tobacco brands

Brands	nap	acpy	flu	acp	phn	ant	fln	bap	chr	bbf	pyr	Total (ng/cig)
C1	400	76	267	55	29	9.1	45	10.11	11.3	5.14	57.6	965.25
C2	278	198	284	11.4	77	44.8	78	11.14	12.9	6.23	59.4	1060.87
C3	392	87	189	65	88	56.3	90	17.15	18.1	3.54	21.3	1027.39
C4	229	59	155	51.1	52	76.4	54	22.51	22.3	6.17	84.8	812.28
C5	378	98	245	13.9	61	34.11	66	7.14	15.9	4.42	57.7	981.17
C6	345	177	54	78.2	78	61.1	39	5.93	15.12	4.60	62.4	920.35
C7	112	109	38	34.2	91	12.8	56	12.42	20.6	7.22	41.2	534.44
C8	267	56	77	65.8	123	14.4	46	14.65	23.9	5.25	35.5	728.5
C9	324	79	65	34.8	144	67.5	48	17.75	25.7	8.51	79.3	893.55
C10	386	99	37	18.6	45	77.6	67	8.16	16.5	4.46	41.3	800.62
C11	138	35	188	15.4	67	82.2	82	5.13	12.5	2.60	75.1	702.93
C12	259	65	56	13.9	17	12.6	76	11.9	18.55	5.42	26.12	561.47
C13	101	87	33	8.2	82	23.8	39	13.9	18.26	6.11	61.9	474.17
C14	287	59	98	45.8	41	29.3	72	11.0	10.9	3.63	84.1	741.7
C15	367	39	54	33.9	166	18.9	81	12.8	21.5	5.11	38.4	837.6
C16	369	66	10	87	67	45.6	90	17.2	27.02	5.18	72.1	856.02
C17	289	78	77	73.6	89	5.8	86	18.0	20.33	4.24	35.2	776.13
C18	356	62	87	77.0	45	7.7	83	11.6	16.56	3.12	21.8	770.78
C19	129	73	83	62.0	76	9.2	56	8.31	17.57	2.92	33.8	550.78
C20	289	99	79	69	87	86.3	44	12.79	15.69	5.14	81.3	868.22
C21	187	76	39	71.4	44	71.2	67	7.9	15.97	5.34	28.6	613.41
C22	111	78	66	53.0	123	33.9	83	2.0	13.53	4.23	75.8	643.46
C23	246	64	93	67.0	111	71.4	45	12.8	15.03	6.81	66.3	798.34
C24	298	69	26	77.2	123	18.7	61	12.2	26.13	7.33	54.9	773.46
C25	267	98	59	67.3	129	23.8	77	10.0	15.52	5.55	22.4	774.57
Average	272.16	83.44	98.36	49.98	82.2	39.78	65.24	11.77	17.89	5.12	52.73	624.37
Min	101	35	10	8.2	17	5.8	39	2	10.9	2.66	21.3	474.17
Max	400	198	284	87	166	86.3	90	22.51	27.02	8.57	84.8	1060.87
SD	93.64	35.621	75.69	24.52	36.85	26.84	16.63	4.50	4.46	1.42	20.96	151.90

*PAHs: naphthalene (nap), acenaphthene (acpy), fluorene (flu), acenaphthene (acp), phenanthrene (phn), anthracene (ant), fluoranthene (fln), benzo[a]pyrene (bap), chrysene (chr), benzo[b,k] fluoranthene (bbf), and pyrene (pyr).

DISCUSSION

PAHs and other compounds have been identified in tobacco components and in mainstream cigarette smoke in previous studies. Generally, the findings of the present study agree with those of Yershova et al.[14] who measured sixteen PAHs compound amounts in mainstream cigarette smoke by gas chromatography–mass spectrometry. They determined the amount of three PAHs compounds: 15 ± 69 ng/cigarette for benzo[a]pyrene, 119 ± 66 ng/cigarette for phenanthrene, and 37 ± 619 ng/cigarette for pyrene. Their results are comparable to the values of the present study.

Limitations

Limitations include the small sample size of products assessed.

CONCLUSIONS

Smoking of cigarettes is a concern as it is an essential cause of inhalation of highly toxic elements, not only to the smoker but also, through passive smoking, to non-smokers. The results of this study provide an overview of four heavy metal concentrations (Pb, Cd, Cr, and Zn) measured in tobacco products. This study also provides a survey of

PAH mainstream smoke yields of popular cigarette brands consumed in Iraq. The study identifies essential variations in PAH levels in the mainstream smoke of different commercial cigarettes. We propose a more detailed study to be conducted on the many other toxic metals present in tobacco products for a comprehensive understanding of the toxicity of tobacco products.

REFERENCES

1. Kibet J, Kurgat C, Limo S, et al. Kinetic modeling of nicotine in mainstream cigarette smoking. Chem Cent J. 2016;10(1):60. doi:10.1186/s13065-016-0206-8
2. Forster M, Liu C, Duke MG, et al. An experimental method to study emissions from heated tobacco between 100-200°C. Chem Cent J. 2015;9(1):20. doi:10.1186/s13065-015-0096-1
3. Viana GF, Garcia KS, Menezes-Filho JA. Assessment of carcinogenic heavy metals in Brazilian cigarettes. Environ Monit Assess. 2011;181(1-4):255-265. doi:10.1007/s10661-010-1827-3
4. Caruso RV, Richard J, O'Connor W, Stephens E, Cummings M, Geoffrey TF. Toxic Metal Concentrations in Cigarettes Obtained from U.S. Smokers in 2009: Results from the International Tobacco Control (ITC) United States Survey Cohort. Int J Environ Res Public Health. 2014;11(1):202-217. doi:10.3390/ijerph110100202
5. Omari MO, Kibet JK, Cherutoi JK, Bosire JO, Rono NK. Heavy Metal Content in Mainstream Cigarette Smoke of Common Cigarettes Sold in Kenya, and their Toxicological Consequences. Int Res J Environment Sci. 2015;4(6):75-79. http://www.isca.in/IJENS/Archive/v4/i6/12.ISCA-IRJEvS-2015-088.pdf. Accessed March 17, 2020.
6. Stojanović, D, Nikić, D, Lazarević K. The level of nickel in smoker's blood and urine. Cent Eur J Public Health. 2004;12(4):187-189. PMID:15666455.
7. Galazyn SM, Brzóska MM, Moniuszko JJ. Estimation of Polish cigarettes contamination with cadmium and lead, and exposure to these metals via smoking. Environ Monit Assess. 2008;137(1-3):481-493. doi:10.1007/s10661-007-9783-2
8. Richter PA, Bishop EE, Wang J, Swahn MH. Tobacco smoke exposure and levels ofurinary metals in the U.S. youth and adult population: the National Health and Nutrition Examination Survey (NHANES) 1999–2004. Int J Environ Res Public Health. 2009;6(7):1930-1946. doi:10.3390/ijerph6071930
9. Tellez PM, Navas AA, Caldwell KL, Menke A, Muntner P, Guallar E. Reduction in cadmium exposure in the United States population, 1988-2008: The contribution of declining smoking rates. Environ Health Perspect. 2012;120(2)204-209. doi:10.1289/ehp.1104020
10. Jeffery J, Carradus M, Songin K, Pettit M, Pettit K, Wright C. Optimized method for determination of 16 FDA polycyclic aromatic hydrocarbons (PAHs) in mainstream cigarette smoke by gas chromatography–mass spectrometry. Chem Cent J. 2018;12(1):27. doi:10.1186/s13065-018-0397-2
11. Singh SV, Vashishth A, Ali A. Polycyclic Aromatic Hydrocarbons in Cigarette Smoke. Punjab Academy of Sciences Journal. 2009;5-6(1&2):134-136. https://www.academia.edu/8213132/Polycyclic_Aromatic_Hydrocarbons_in_Cigarette_Smoke. Accessed March 17, 2020.
12. Siaka M, Owens CM, Birch GK. Evaluation of Some Digestion Methods for the Determination of Heavy Metals in Sediment Samples by Flame-AAS. Analytical Letters. 1998;31(4):703-718. doi:10.1080/00032719808001873
13. Stepanov I, Knezevich A, Zhang L, Watson C, Hatsukami DK, Hecht SS.Carcinogenic Tobacco-Specific N-Nitrosamines in U.S. Cigarettes -Three Decades of Remarkable Neglect by the Tobacco Industry. Tob Control. 2012;21(1):44-48. doi:10.1136/tc.2010.042192
14. Yershova K, Jian-Min Yuan M, Wang R, et al. Tobacco-specific N-nitrosamines and polycyclic aromatic hydrocarbons in cigarettes smoked by the participants of the Shanghai Cohort Study. Int J Cancer. 2016;139(6):1261-1269. doi:10.1002/ijc.30178

CONFLICTS OF INTEREST
The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

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