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RESEARCH ARTICLE

The Relationship Between Cadmium Contents of Tobacco and Their Ash in Cigarettes Marketed Under Different Brands

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Summary

Cadmium (Cd) is a heavy metal most commonly responsible for a number of pathologies, such as end-stage renal failure, early onset of diabetic renal complications, osteoporosis, and increased cancer risk. The aim of this study was to investigate Cd levels in tobacco, the main route exposure, and their ash of different cigarette samples marketed in Turkey and to evaluate the inhaled amounts of Cd exposure. The level of Cd in tobacco and their ash of 20 different brands of cigarettes were determined by Graphite Furnace Atomic Absorption Spectrometry. Regarding to the measurements, Cd levels in tobacco were found between 503-2742 ng/cigarette. Considering the Cd amounts measured in ash of tobacco, 1.29 % - 14.3 % of Cd stayed in ash without combustion, so it can be figured out that 85.7 % - 98.71 % of Cd spreads into the air and inhaled by the smokers. As a result, this study proved us much of Cd levels in tobacco were released into the air and lungs during smoking. For this reason smokers and passive smokers exposed to Cd in excessive amounts during their smoking habits.

Key Words: *Cadmium, heavy metal, inhalation, ash, tobacco*

Türkiye'de Satılan Sigaraların Tütün ve Külünde Kadmiyum İçeriğinin Değerlendirilmesi

Özet

Kadmiyum (Cd) böbrek yetmezliği, diyabetik böbrek komplikasyon başlangıcı, osteoporoz ve kanser riskinde artış gibi birçok patolojiden sorumlu tutulan bir ağır metaldir. Bu çalışmanın amacı Türkiye'de pazarlanan sigara örneklerinin tütün ve külünde Cd düzeylerini araştırmak ve inhale edilen Cd miktarını değerlendirmektir. Bu amaçla 20 farklı markanın tütün ve küllerin Cd içeriği Grafit Fırın Atomik Absorption Spektrometrisi ile tespit edilmiştir. Ölçümler değerlendirildiğinde, tütünlerde Cd içeriği 503-2742 ng/sigara olarak bulunmuştur. Tütünlerin külünde ise % 1.29 - 14.3 Cd tespit edilmiş, dolayısıyla Cd'un % 85.7 - 98.71'inin havaya yayıldığı veya sigara içenler tarafından inhale edildiği saptanmıştır. Sonuç olarak, bu çalışma sigara içerken sigaradaki Cd içeriğinin büyük kısmının akciğerlere ve havaya yayıldığını göstermiştir. Bu sebeple, sigara içenler ve pasif içiciler sigara içme alışkanlıkları sırasında aşırı miktarda Cd'a maruz kalmaktadır.

Anahtar kelimeler: *Kadmiyum, ağır metal, inhalasyon, kül, tütün*

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INTRODUCTION

Tobacco (*Nicotiana tabacum* L.) is an important crop plant and a member of the nightshade (Solanaceae) family [1]. It's use is one of the main risk factors for a number of chronic diseases, including cancer, lung diseases, cardiovascular diseases, human reproductive system diseases and immunological function alterations [2,3]. Smoking kills up to half of its users. Nearly six million people each year, even more than 600.000 nonsmokers, lost their lives. According to World Health Organization (WHO), unless urgent action is taken, the annual death toll could rise to more than eight million by 2030 [3].

Tobacco smoke contains toxic compounds include nicotine, carbon monoxide, polycyclic aromatic hydrocarbons, thiocyanate, and approximately 30 metal ions including cadmium (Cd), lead, nickel, chromium, arsenic, aluminum, antimony, copper, and iron, as well as radioactive elements [4].

Smoking is an important source of Cd exposure. Smokers have about twice as much Cd in their bodies as do nonsmokers. Other sources of airborne Cd in the environment are the burning of fossil fuels such as coal or oil, and incineration of municipal waste materials. For nonsmokers, food is generally the largest source of Cd exposure [5]. After absorption, Cd is poorly (only about

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0.001 % of the body burden per day) excreted and the biological half-life of Cd in humans is probably in the range of 10-30 years [6]. Therefore Cd concentrations in most tissues increase with age and mainly stored in the liver and kidneys. Chronic exposure to low-level Cd has been associated with a number of pathologies, such as end-stage renal failure, early onset of diabetic renal complications, osteoporosis, deranged blood pressure regulation, increased cancer risk and skeletal damage [7]. According to the International Agency for Resaerch on Cancer (IARC), Cd is classified as Group 1 human carcinogen [8]. However, Cd is not considered as a carcinogen by ingestion, carcinogenic effects can be seen by the inhalation route [9]. The absorption of Cd is much lower after an oral intake (4-8%) than on inhalatory exposure (15 to 40%). Epidemiological data from occupational settings confirm lungs being the primary target organ [9]. Due to the toxicological importance of this metal, we investigated Cd levels in tobacco and ash of different cigarette samples marketed in Turkey and we evaluated the inhaled amounts of Cd exposure.

MATERIAL AND METHODS

Commercially available 20 different brands of local and imported cigarettes were purchased from the local market of Turkey between 2011 and 2012. These cigarettes were produced from six different sources of tobacco. Brand names have not been disclosed in this paper.

For analysis of Cd, filter part and wrapping paper of cigarettes were removed. Tobacco from each brand was weighted separately. All the glassware were cleaned with acid mixture of HNO_3:HCl, 1:3 v/v in order to avoid any contamination. All reagents used were of analytical grade. Cadmium standard solution (Fluka Analytical) was used to prepare working standard solutions.

The known quantity of sample was digested with 4 ml of concentrated nitric acid (HNO_3) (Merck, 65 %) in the water bath for 4.5 hours under laboratory hood. After waiting for 24 hours, samples were put in the water bath for 2 more hours. Final volume was completed to 5 ml with concentrated HNO_3. Cigarettes from each brand were smoked by a volunteer to collect ash of cigarette. Smoking was stopped when the burning line reached the butt length. Ashes from each brand were digested with freshly prepared mixture of HNO_3:HF 5:2, v/v in microwave acid digestion unit (Milestone, Mega 1200) till the clear transparent digests was obtained. Results were tested with a control blank and quality control solutions. This procedure was repeated after every five samples. The calibration curve was prepared from Cd standard solution at 0.3 – 3 ng/ml concentration range in the same acid concentration to minimize matrix effects.

The Cd levels in tobacco and their ash of different brands of cigarettes were measured by Graphite Furnace Atomic Absorption Spectroscopy (Analytic Jena, ZEEnit 700) equipped with Zeeman background correction. Suitable dilutions were made from digested tobacco and their ash samples with ultrapure distilled water (Simplicity Water Purification System). The manufacturer's application notes were used for Cd measurements checking validation parameters. Detailed information about graphite furnace parameters was shown in Table 1.

RESULTS AND DISCUSSIONS

Cd levels in tobacco were higher than those in the ash, and the results showed great differences among brands of cigarettes (Table 2). Regarding to the measurements, Cd levels were found higher than 1200 ng in four tobacco

Table 1. Graphite furnace parameters for the determination of Cd levels

No	Type	Temperature [°C]	Rate [°C/s]	Hold [s]	Time [s]	Gas Inert.	Gas Add.g
1	Drying	90	5	20	33,8	Max	Stop
2	Drying	105	3	20	25	Max	Stop
3	Drying	110	2	10	12,5	Max	Stop
4	Pyrolsis	800	250	10	12,8	Max	Stop
5	AZ*	900	0	4	4	Stop	Stop
6	Atomize	1500	1500	3	3,4	Stop	Stop
7	Cleanout	2300	500	4	6	Max	Stop

*AZ: Auto zero phase of graphite furnace.

Table 2. Cadmium levels in tobacco and their ash of 20 different branded cigarettes marketed in Turkey

	Tobacco			Ash of Tobacco		
No	Weight of tobacco samples per cigarette (g)	Cd level (ng/cigarette)	Cd level (ng/g)	Weight of ash per cigarette (mg)	Cd level of ash (ng/cigarette)	Cd % in ** cigarette ash
1	0.5	2160.31	4320.62	97.73	97.52	4.51
2	0.5	1260.45	2520.90	79.95	41.94	3.33
3	0.5	772.06	1544.12	84.61	110.40	14.30
4	0.5	2741.73	5483.46	126.61	166.47	6.07
5	0.5	760.91	1521.82	95.43	39.64	5.21
6	0.5	842.21	1684.42	201.21	42.88	5.09
7	0.5	830.41	1660.82	118.07	40.56	4.88
8	0.5	978.63	1957.26	90.89	58.27	5.95
9	0.5	791.76	1583.52	94.69	27.37	3.46
10	0.5	645.31	1290.62	80.96	23.40	3.63
11	0.5	555.64	1111.28	87.55	17.95	3.23
12	0.5	503.43	1006.86	84.68	6.47	1.29
13	0.5	752.97	1505.94	95.17	28.40	3.77
14	0.5	655.50	1311.00	95.99	23.31	3.56
15	0.5	850.74	1701.48	81.02	18.86	2.22
16	0.46*	503.35	1094.23	73.49	17.43	3.46
17	0.5	1816.08	3632.16	101.88	63.78	3.51
18	0.5	631.79	1263.58	99.96	27.13	4.29
19	0.5	745.55	1491.10	85.45	41.90	5.62
20	0.5	684.72	1369.44	95.30	25.45	3.72

*This brand of cigarette was 'slim' therefore the weight of the sample was less than the others.
**These percentages were calculated by the comparison of the Cd level in per gram of ash and Cd level in per gram of tobacco. These values represent the Cd level which remains in the ash of tobacco after burning of cigarette.

samples and less than 550 ng in two tobacco samples. Differences may be due to different brands of cigarettes, different sources of tobacco, harvesting times, Cd content of the land, growing conditions and treatment processes. So if the Cd content of the cigarette is higher there will be more serious environmental pollution [10].

According to Ashaf, the amount of Cd inhaled from smoking one pack of 20 cigarettes of different brands was reported to be 1.40-2.70 µg [11]. In our study, the amount of Cd inhaled from smoking one pack of 20 cigarettes was estimated to be 0.12-3.32 µg. The minimum level of Cd was 0.50 µg/cigarette while the highest level was 2.74 µg/cigarette. These results are consistent with researchers from Pakistan (1.05-1.75 µg/cigarette) [12]. In another study conducted by US researchers, Cd content of cigarettes were reported to be in the range of 0.93-1.86 µg/g [13]. In our study, Cd content of 4 brands of cigarettes was higher. In a study conducted on Chinese market, Cd levels were reported as 0.1-4.95 µg/g while our results were 0.81-3.27 µg/g [10].

Cd levels in ash of tobacco were shown in Table 1 as percent of Cd level in tobacco. The results showed that 1.29-14.3 % of Cd in tobacco stayed in ash without combustion. In the view of obtained values, the rest 85.7-98.71 % of Cd was spreaded into the air and lungs of the smokers. Our results were consistent with earlier study which reported the concentration of pollutants in side stream smoke was often higher than that in mainstream smoke. Based on this study, when cigarettes burn, about 5-12% of Cd in the cigarette smoke was suggested to inhale into smoker's body with mainstream smoke, but 33-62% was exhaled into the environment [10]. According to this data, the mean inhaled amounts of Cd exposure were calculated to be 1-2.4 µg from one package (20 cigarettes). In addition, the highest inhaled amounts of Cd exposure were calculated to be 2,8 - 6,6 µg from one package (20 cigarettes).

A typical cigarette smoker inhales mainstream smoke 8 to 10 times, for a total of 24 to 30 seconds out of total 12 minutes burn time for the typical cigarette. Hence, side stream smoke is produced during 96% of the total time when a cigarette is lit; it is the side stream smoke that is the most important source of environmental pollution, especially indoor pollution [10]. The amount of Cd spreaded into the air from smoking one pack of 20 cigarettes was estimated to be 9,7 – 50 μg and the average amount of 20 different brands of Cd spreaded into the air was estimated to be 20 μg. This study proved us again that cigarette smokers exposed to Cd, a life threatening heavy metal, in excessive amounts during their smoking habits. It should be also stressed that passive smokers especially in a closed area are under the great risk for Cd exposure. Considering the elimination rate and the long half-life of Cd in human body, chronic exposure to Cd by smoking or by side stream smoke, may cause undesired health effects.

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