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Full Length Research Paper

Cadmium determination in cigarettes available in Nigeria

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Cadmium (Cd) contents were determined in 30 brands of tobacco cigarette commonly available in Nigeria by atomic absorption spectrophotometry. The concentration of Cd in the cigarettes ranged from 0.7 to 2.3 g/g dry weight with mean 1.48 $\pm$ 0.46 g/g. Higher Cd concentrations were found in imported brands (1.52 $\pm$ 0.46 g/g) compared to the Nigerian brands (1.10 $\pm$ 0.35 g/g). Relatively lower Cd values were observed in cigarettes from developing countries (~ 1.3 g/g) compared to brands from developed countries (>1.3 g/g). The average Cd content of cigarettes available in Nigeria is 1.28 g per cigarette and a person who smokes 20 cigarettes per day is estimated to increase his daily Cd retention by approximately 1 g/day (0.53 – 1.65 g/day). The results indicate that smoking and exposure to cigarette smoke is a confounder to be taken into account when carrying out epidemiological studies on human exposure to cadmium.

Key words: Cigarettes, tobacco, cadmium, Nigeria, smoke.

INTRODUCTION

Cigarette is one of the means by which nicotine in tobacco is made available for human consumption. Nicotine is recognized to be the major inducer of tobacco dependency (Hoffmann and Hoffmann, 1997). Approximately 5 trillion cigarettes are produced each year or 1,000 cigarettes for each man, woman and child on earth (HRO/World Bank, 1993) . Usually, cigarette is made up of tobacco, paper and additives. As much as 600 – 1400 additives are used in cigarette manufacture, with many of these additives containing trace elements that include Cd (Ebisike et al., 2004). A study of more than 300 ingredients added to cigarette reported an increase in the yield of total particulate matter (TPM) in the range of 13 - 28% relative to the cigarettes without these ingredients (Rustemeier et al., 2004). This was attributed to the higher transfer rates of the added ingredients to smoke.

Since 1950, the make up of cigarettes and the composition of cigarette smoke have gradually changed. The “tar” and nicotine levels have decreased from 38 mg tar and 2.7 mg nicotine to as low as 12 mg tar and 1.0 mg nicotine. This was achieved primarily with the introduction of filter tips, (with and without perforation), selection of tobacco types and varieties, utilization of highly porous cigarette paper and incorporation into the tobacco blend of reconstituted tobacco and “expanded tobacco”, (Hoffmann and Hoffmann, 1997) . The “tar” and nicotine content of cigarettes available in Nigeria are in the range of 12 – 18 mg and 0.7 – 1.4 mg, respectively.

Cigarette smoke contains particles and gases generated by the combustion of its various components at high temperature. More than 4000 compounds have been identified in environmental tobacco smoke (Kleeman et al., 1999). The cigarette smoke can be inhaled directly by the smoker and non-smokers in cigarette contaminated environment through passive smoking. Cadmium is a known carcinogen and is one of the components of tobacco. It has been proved quantitatively that exposure to cigarette smoke is harmful to both active and passive smokers. Shaham et al. (1996) observed that exposure to cigarette smoke via

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active and passive smoking increases blood Cd by an average of 0.01 g% over the background (unexposed non-smokers).

Smoking of cigarettes as an advantageous delivery system for nicotine, accelerates and aggravates cardiovascular diseases, and is causally associated with increased risks of chronic obstructive lung disease, cancer of the lung, and of the upper aerodigestive system (Hoffmann and Hoffmann, 1997). Cigarette smoke impairs both male and female fecundity and may potentiate the effects of other suspected reproductive toxicants such as caffeine (Curtis et al., 1997; Benoff et al., 2000). Although the blood concentration of Cd may be increased in smokers (Friberg and Vahter, 1983; Jabukowski et al., 1996), it is more likely that the negative effect of smoking on semen quality are as a result of the observed trend for Cd in tobacco smoke to accumulate in the genital tract of smokers. Not only are smokers at risk, a positive correlation has been observed between the degree of passive exposure to cigarette smoke and the concentration of components of cigarette smoke in seminal plasma (Benoff et al, 2000). Cadmium levels in human milk have also been reported to be correlated strongly with exposure to cigarette smoke both when the mother smoked and when the father smoked and the mother did not smoke (Dabeka et al., 1986). A recent study by Ebisike et al. (2004) reported high levels of Pb, Zn, Cd, Cu and Ni in the saliva of smokers in Nigeria. This was also observed to be highly correlated with the level of these metals in the cigarette.

The high level of Cd in the body tissues of smokers has been attributed to two factors by Elinder et al. (1983a). The first is the Cd content of cigarette, which is relatively high, usually in the order of 0.5 to 2.0 g/g compared to that normally found in foodstuffs. The second factor is that the pulmonary absorption of inhaled Cd is much higher in the order of 25 to 50% of the inhaled amount compared to 1 to 10% when ingested (Elinder et al., 1983a).

The concentration of Cd in cigarette is of importance because of the toxicological effects of this metal. Heavy metals in cigarettes are present in the mainstream smoke (inhaled by the smoker during a puff), in sidestream smoke (smoke produced mainly between the puff and probably inhaled by non-smokers), in the butt and in the ash (Elinder et al., 1983a; Ebisike et al., 2004). About 50% of the Cd mobilized by the smoking process is transferred into the side stream smoke whereas the amount of Cd in the main- stream smoke increases as the number of puffs is increased (Kalcher et al., 1993).

In the present study, we have determined the level of Cd in cigarette available in Nigeria and estimated the amount of Cd inhaled from the consumption of such cigarettes.

MATERIALS AND METHOD

Thirty (30) brands of cigarettes commonly available in Nigeria were purchased from retail outlets in Okigwe, Umuahia and Onitsha in Southeastern Nigeria. These are London (king size and menthol), Marlboro (filter and light), Benson and Hedges, Rothmans, Consulates, St. Moritz, L&M, Dorchester (king size and menthol), Aspen Export, Bond Street, John Player Gold Leaf, DJ Mix, Business Club, Gold Seal (filter and menthol), Superkings, Compliment, Ashford, Rover, Dunhill International, Target, Ashton International, L&B, Sweet Menthol and Gold Bond. The average weight of each cigarette brand was determined by weighing 5 sticks of each brand before and after removing the filters. Composites of each brand were prepared by removing the papers and filters of 5 cigarettes selected from a pack of 20.

The samples were dried in an oven at a temperature of 80°C for 12 h and allowed to cool in a dessicator. The method of Elinder et al. (1983) was used. 5 g of each cigarette sample was ashed at 450°C in a muffle oven. 1 g of the ash was treated with concentrated HNO_3 and heated to near dryness. The digest was taken up in 1 M HNO_3, filtered through No. 4 Whatman filter paper into a volumetric flask and made up to volume with deionized water. This was subsequently analyzed for cadmium at a wavelength of 228 nm using flame atomic absorption spectrophotometer (UNICAM, 969). Internal quality control with re-tests of cadmium standards prepared in 1 M HNO_3 was undertaken. Digestion blanks were also included and results reported are average of duplicates.

RESULTS AND DISCUSSION

The weight of the cigarettes ranges from 0.91 to 1.16 g (mean, 1.02 g) . The weight of the cigarettes removing the papers and filters varies depending on the length of the cigarette. The average weight of the cigarettes without the fitter is 0.86g (range 0.77 – 0.96 g). Cigarette filters have been observed to significantly prevent the inhalation of Cd, Pb, Mg and Fe (Mussalo-Rauhamaa et al., 1986)

The mean Cd concentration of the cigarette brands studied is 1.48 $\pm$ 0.46 g/g dry weight (range 0.7 – 2.3 g/g). The Cd concentrations of the cigarettes according to the countries of origin are shown in Table 1. The average cadmium content of cigarettes available in Nigeria is 1.28 g/cigarette (range 0.60 – 1.98 g Cd per cigarette). This is in agreement with observations reported elsewhere by Elinder et al. (1983a) (1.76 g Cd per cigarette) and Friberg et al. (1974) (1.56 – 1.96 g Cd per cigarette).

The mean cadmium content of Nigerian cigarettes, 1.10 $\pm$ 0.35 g/g (range 0.90 – 1.50 g/g) is lower than the mean Cd content of the imported brands, 1.52 $\pm$ 0.46 g/g (range 0.70 – 2.30 g/g). The Cd content of the cigarette brands from Cameroun (1.30 g/g) and Nigeria (1.10 g/g) are lower than the values for cigarettes from Germany, Netherlands, Switzerland, United States and the United Kingdom (Table 1). This corroborates the results of Elinder et al. (1983a) and Nwankwo et al. (1977) who independently reported lower values for Cd in cigarettes from developing countries compared to

Table 1. Cadmium content (g/g, dry weight) of Nigerian and some overseas brands of tobacco cigarette.

Country	Cadmium Concentration		N
	Mean (±SD)	Range	
Cameroun	1,3		1
France	2.3		1
Germany	1.80±0.45	1.2-2.2	4
Nigeria	1.27±0.42	0.9-1.9	7
Switzerland	1.9		1
United Kingdom	1.34±0.48	0.7-2.3	11
United States	1.62±0.29	1.2-1.9	5

Table 2. Comparison between the present result and available reported levels of cadmium in cigarette.

Source of cigarette	Mean (±SD)	Range	Reference
New Zealand, US, Switzerland, France, UK		0.03-1.66 µg/g (13)*	Brooks and Trow, 1979
Argentina, Finland, India, Japan, Sweden Mexico, China, Sri Lanka	1.67±0.38 µg/g	0.19-3.04 µg/g 0.93-2.41 µg/cigarette (26)	Elinder et al., 1983
Cigarettes available in Asia	1.45 µg/g	0.29-3.38 µg/g 1.15 µg/cigarette (331)	Watanabe et al., 1987
Poland, Cuba, Yugoslavia, Albania		0.98-4.15 µg/g (12)	Zawadzka et al., 1989
Mexico	4.41±0.67 µg/g	1.0-4.5 µg/g 2.8µg/cigarette (55)	Saldivar et al., 1991
Korea, United Kingdom	1.029 (Korea)	0.91-1.13 µg/g 0.64-0.86 µg/cigarette	Jung et al, 1998
	0.90 (UK)	0.69-1.10 µg/g 0.50-0.79 µg/cigarette	
Cigarettes available Nigeria		0.013-0.016 mg/g 0.097-0.119 mg/cigarette (8)	Spiff et al., 1999
Cigarettes available Nigeria		0.68-1.17 µg/g (6)	Ebisike et al., 2004
Switzerland, Nigeria, Cameroun, US,UK, Germany, France	1.48±0.46 µg/g 1.28 µg/cigarette	0.7-2.3 µg/g 0.6-1.98 µg/cigarette (30)	Present Study

*Values in bracket indicates the number of sample studied.

developed countries. Nwankwo et al. (1977) obtained a range of 0.14 to 0.24 g/g dry weight for cigarettes from Zambia and Tanzania compared to1.2 g/g dry weight in an American brand. Similarly, Elinder et al. (1983a) reported a range of 1 to 2 g/g for cigarettes from Sweden, Finland and Japan and significantly lower values, less than 0.93 g/g dry weight, for cigarettes from Argentina, India, Peoples Republic of China, and Sri Lanka.

Our result agrees with earlier observation that the mean Cd of cigarettes varied markedly depending on the area of production. However it has not been possible to obtain any evidence to suggest that the differences are related to the area of production or the extent of industrial development of the area (Watanabe et al., 1987). A comparison of the result of studies of the Cd content of cigarette in various parts of the world and results of the present study are shown in Table 2.

It is likely that the major source of Cd in tobacco smoke and the high concentrations of Cd in tobacco leaves and cigarettes probably result from the widespread use of chemical fertilizers. The excessive use of fertilizers and pesticides, and irrigation with residual water are among the causes of contamination of raw foodstuff (Cabrera et al., 1995) and tobacco leaves (Cekic, 1998). Some species of plant have been observed to accumulate high concentrations of some metals, most especially Cd, in leaf tissue rather than in roots (Myers, 1990).

The processing, packaging and other technological processes (including the use of additives) used to bring raw food items to the consumer can significantly increase the total concentration of trace metals in the finished products (Cabrera et al., 1999; Creaser and Purchase, 1991). With the increased production and man-made emission of cadmium (Nriagu, 1980), it is also possible that changes in the cadmium content of cigarette tobacco has taken place as a function of time (Elinder et al., 1983a).

A potential role of cigarette smoking in the development of cataract has been established by a series of epidemiological studies (West et al., 1989). Smoking appears to induce oxidative stress in that smokers have diminished levels of antioxidants such as vitamin C, vitamin E and carotenoids. It has been observed that Cd may directly interact with lens protein and denature them in cataractogenesis (Cekic, 1998)

Of toxicological importance is the amount of metal the smoker inhales into his lungs. This has been assumed to be the amount going into the mainstream smoke (Elinder et al., 1983a). Studies with smoking apparatus have indicated that approximately 10% of the Cd content of cigarette is found in the mainstream smoke (Elinder et al., 1983a; Menden et al., 1972; Benoff et al., 2000). Thus an average of 0.14 g Cd (range 0.07 – 0.22 g Cd) is inhaled from smoking one cigarette in Nigeria. Menden et al. (1972) and Elinder et al. (1983) reported ranges of 0.01 – 0.12 g Cd/cigarette and 0.14 – 0.19 g Cd/cigarette, respectively, using smoking apparatus.

Assuming a 25 to 50% absorption of inhaled Cd (Friberg et al., 1974) it is estimated that a person who smokes one pack of cigarette (20 cigarettes) a day in Nigeria would increase his daily Cd retention by about 1.05 g (range 0.53 – 1.65 g). An increase of 1.4 to 2.8 g Cd/day and 2 g Cd/day have been estimated per pack of cigarette for smokers in Mexico and Japan, respectively (Saldivar et al., 1991; Watanabe et al., 1983). A similar estimate (0.8-1.5 g Cd/day) was also reported by Elinder et al., (1983a) . With an estimated Cd intake from food (ingestion) of 1 g/day (Elinder et al., 1983b) and respiration (inhalation) of 0.05 g/day (Watanabe et al., 1983), a smoker in Nigeria increases his Cd exposure by a factor of 2.

The report of an international (WHO/UNEP) program for assessment of human exposure to heavy metals, reported higher levels of Cd in kidney cortex samples of smokers compared to non-smokers in Europe, United States and Japan (Friberg and Vahter, 1983). This study observed that on the average, smokers had about 4 times higher blood Cd than non-smokers. The mean Cd content of fat tissues of male smokers has also been observed to be about 4 times that of non-smokers (Mussalo-Rauhamaa et al., 1986). Median blood Cd levels of 1.4 g/L and 0.2 g/L have been reported for smokers and non-smokers, respectively (Elinder et al., 1983b) . This difference in blood Cd level has been shown to be significant at all age ranges with an increase of about 0.8-1.4 ng/mL (Watanabe et al., 1983). Significantly higher concentrations of Cd and Pb have also been reported in blood (Tola and Nordman, 1977), hair (Wolfsperger et al., 1994) and saliva of smokers (Ebisike et al., 2004).

Tobacco consumption through cigarette is a problem assuming an alarming proportion in Nigeria. Statistics also revealed that more than 10,000 millions sticks of cigarettes were consumed in Nigeria in 1995 with an average of 300 cigarettes per person per year (Ebisike et al., 2004; Shafey et al., 2003). The observation that it is becoming increasingly difficult to quit smoking has necessitated research at developing a vaccine which intercepts the nicotine in the blood stream and prevents it from reaching the brain to induce the so-called 'reward'.

This study shows that the level of Cd in cigarettes available in Nigeria compares well with levels in cigarettes from other parts of the world. The data here obtained will be valuable in complimenting available data on Cd exposure from cigarette consumption, and in estimating dietary intake of heavy metals in Nigeria. Efforts should be made by the government at discouraging consumption of cigarettes.

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