Bull. Environ. Contam. Toxicol. (1998) 61:276-280

Bulletin of Environmental Contamination and Toxicology

Vanadium Content of Cigarettes

A. Adachi, K. Asai, Y. Koyama, Y. Matsumoto, T. Kobayashi

Kobe Pharmaceutical University, Motoyamakitamachi 4-chome, Higashinada-ku, Kobe 658, Japan

Received: 27 March 1998/Accepted: 8 June 1998

Environmental pollution due to vanadium has become a serious problem. Vanadium in air originates mainly from combustion of fuel oils , especially residual oils, which are known to be rich in this element, while the contribution of heavy vehicular traffic seems to be of minor importance, in agreement with experimental measurements and the known low vanadium levels in distillate petroleum used in land transport. It has been shown that the burning of fossil fuels results in 12000 - 24000 tons of vanadium per year, of which roughly 10 - 15 % is deposited in the ocean as atmospheric fallout (Bertine et al. 1971). The toxic action of vanadium is largely confined to respiratory tract. Irritant activity with respect to the skin and eyes has also been described to industrial exposure (Browning 1969). Although there is no direct evidence on toxicity levels for continuous year round exposure, British sources (Stocks 1960) report a statistical relation between vanadium concentration in rural and urban air pollution and the incidence of lung cancer, bronchitis and pneumonia. Athanassiadis (1969) has reported at length on the toxicity of vanadium compounds and on the major sources of emissions. Several studies (Cantley et al. 1977, 1978, Higashino et al 1983) have demonstrated that vanadium is a potent inhibitor of the ubiquitous enzyme (Na,K)-ATP ase in erythrocytes and renal tubular cells of various species. Tobacco plants tend to absorb metals from the soil and to accumulate in the leaves. Therefore, the heavy metal content of cigarettes has been a subject of study since the early 1950s (Carl et al. 1985, Carl et a1.1986, Watanabe et al, 1987, Rickert et al. 1994). Since few detailed reports have been made as to the assay of vanadium in cigarette, we investigated this.

MATERIALS AND METHODS

Forty five different brands of cigarettes were used. Cigarette samples were dried on a hot plate at 120°C for 2h and ashed at 250°C for 2h and at 550°C for 6 h in a muffle furnace. The residue was dissolved in 5% HCl 1ml and the resulting solution was made up to 10 ml with distilled water. The solution was subjected to atomic absorption spectrophotometry. The recoveries of added

Correspondence to: A. Adachi

vanadium in various kinds of cigarettes were 95.3 and 108.0 %, with a maximum coefficient variation of 7.9 %. The smoking machine consisted of vacuum pump and flowmeter (Figure 1). This machine was used for the determination of vanadium in ash, filter and cigarette smoke. The actual flow was regulated by needle valve. The ash was collected in a plate.

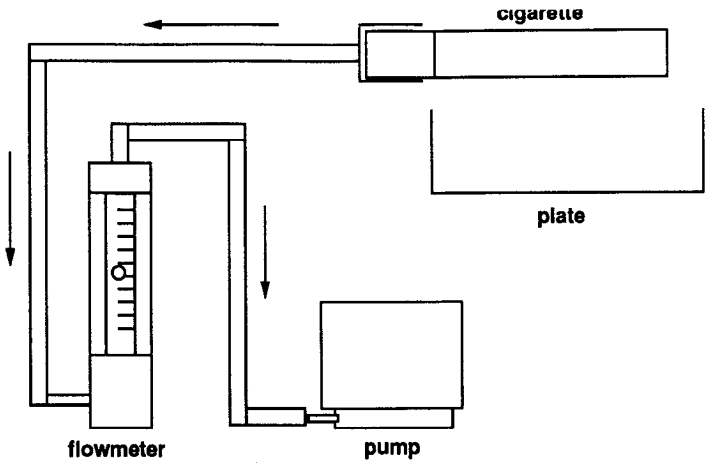

Figure 1. Setup of the smoking machine

RESULTS AND DISCUSSION

Table 1 shows the assayed values of vanadium and nickel in cigarettes before smoking. These elements are generated from some crude oil. Emissions from the combustion of oil are the major contributor of environmental pollution. Therefore, nickel was assayed too. In cigarettes, vanadium concentrations range from 0.49 to 5.33 µg/g. Those of nickel were between 2.22 and 6.70 µg/g. The average concentration of vanadium and nickel were 1.83 and 4.47 µg/g , respectively, and the ratio of the latter to the former was 2.4 % (Table 2). There was a highly significant correlation between the concentration of tar and nicotine in cigarettes, as shown in Table 3 (r = 0.766). On the other hand, no significant correlation was found between the other items. Table 4 shows the vanadium content of whole unsmoked cigarettes, ash, filter and smoke. Six different brands were used on this purpose. The amount of the element contained in the cigarette smoke was estimated by subtracting the values for ash plus filters from the mean content of the whole cigarette. The vanadium and nickel contents of

Table 1. Assayed values of vanadium and nickel in cigarettes

Sample	V (μg/g)	Ni (μg/g)	Sample	V (μg/g)	Ni (μg/g)	Sample	V (μg/g)	Ni (μg/g)
1	2.51	2.92	16	1.12	3.65	31	1.11	4.20
2	2.21	3.26	17	0.49	3.46	32	1.65	5.65
3	1.18	4.35	18	2.00	2.22	33	1.49	5.50
4	1.57	4.20	19	2.24	4.86	34	1.01	3.69
5	1.84	4.56	20	1.01	3.69	35	5.33	3.75
6	2.41	6.36	21	1.16	4.93	36	1.20	5.02
7	2.59	3.75	22	1.77	5.11	37	1.93	3.93
8	2.35	5.41	23	1.64	4.09	38	2.11	4.38
9	1.37	4.31	24	0.84	2.42	39	1.84	5.06
10	1.84	4.60	25	0.81	4.37	40	2.30	5.82
11	4.30	5.55	26	0.93	3.98	41	2.16	6.01
12	1.44	6.70	27	4.30	5.67	42	1.32	3.09
13	1.00	4.41	28	3.79	3.84	43	1.79	4.45
14	1.05	5.28	29	0.83	3.63	44	1.53	5.47
15	1.17	5.08	30	2.67	5.02	45	1.12	3.25

Table 2. Concentration of vanadium and nickel in cigarettes

Element	n	Concentration (μg/g)	
		Min - Max	Mean ± S.D.
V	45	0.49 - 5.33	1.83 ± 1.00
Ni	45	2.22 - 6.70	4.47 ± 1.01

the smoke are relatively constant, and represent 31.3 and 31.9 % of the unsmoked cigarettes content, respectively. Nandi et al (1969) reported that about 60 % of the cadmium in a cigarette is estimated to pass ‘into the smoke. Landsberger et al. (1993) described that 80 % of the cadmium in cigarette went to the cigarette smoke. The flux amount of elements into the smoking fractions during the smoking process may depend on its boiling point. Both vanadium and nickel boil at about 3000°C. On the other hand, the boiling point of cadmium is 767 °C. This is compatible with the observation that the temperature at the ignited end of a cigarette can exceed 800 °C. The filters after smoking contained 8.3 % of vanadium. Landsberger et al (1993) reported that the cadmium content of filter from one piece was 3.7 %. Because the filter retains mainly particles, the differences depend on the metal. About 60 % of the vanadium in cigarette remained in ash. Barry et al. (1986) reported that plants vanadium levels increased in the relation to the rate of its supply in the soils.

Table 3. Correlation coefficients among each component in cigarette

	V	Ni	Tar	Nicotine
V				
Ni	0.008			
Tar	0.006	0.121		
Nicotine	0.011	0.051	0.766*	

*:There was a significant correlation among each component, $p<0.01$.

Table 4. Concentration of vanadium in cigarette, ash, filter and cigarette smoke

Sample	Concentration of vanadium (μg/cigarette)			
	Cigarette	Ash	Filter	Smoke
A	1.07	0.75	n.d.	0.32
B	1.44	0.96	0.05	0.43
C	1.59	1.04	n.d.	0.36
D	1.03	0.54	0.17	0.29
E	0.90	0.45	0.13	0.32
F	0.65	0.28	0.02	0.27
Mean ± SD	1.11±0.35	0.67±0.30	0.09±0.07	0.33±0.06
Percentage of whole cigarette (%)	100.0	60.4	8.3	31.3

n.d. : not detected

Its accumulation and transfer from sea water to terrestrial organisms through a mollusca food chain was investigated by Unsal (1982). Vanadium content in shrimp and oyster was higher in specimens taken from industrialized areas compared to nonindustrialized sections around Galveston island, Texas (Blotcky et al 1979). Its concentrations in foods appear to be sensitive to environmental pollution of vanadium. Tobacco plants absorb metals from the soil and to accumulate in the leaves. Therefore, the assayed values of vanadium in cigarette can be used as one of indicator for air pollution by fuel oils.

REFERENCES

Bertine KK, Goldberg ED (1971) Fossil fuel combustion and major sedimentary cycle. Science 173 : 233 - 235

Browning E (1969) Toxicity of industrial metals 2nd ed.Butterworths, London.

Stocks P (1960) On the relation between atmospheric pollution in urban and rural localities and mortality from cancer, bronchitis and pneumonia with particular reference to beryllium, molybdenum, vanadium and arsenic. Brit J Cancer 4 : 937 - 940

Athanassiadis YG (1969) Air pollution aspects of vanadium and its compounds. Litton Systems, Inc., U.S.

Nandi M, Jick H, Slone D, Shapiro S, Lewis GP (1969) Cadmium content of cigarettes. Lancet 20:1329-1330

Cantley LC, Josephson L, Warner R, Yanagisawa M, Lechene C, Guidotti G (1977) Vanadate is a potent Na,K-ATP ase inhibitor found in ATP derived from muscle. J Biol Chem 252:7421-7423

Cantley LC, Cantley LG (1978) A characterization of vanadate interactions with the Na,K-ATPase. J Biol Chem 253 : 7361-7368

Blotcky AJ, Falcone C, Medina VA, Rack E P (1979) Determination of trace-level vanadium in marine biological samples by chemical neutron activation analysis. Anal Chem 51 : 178 - 183

Unsal M (1982) The accumulation and transfer of vanadium within the food chain. Mar Pollut Bull 13 : 169 - 141

Higashino H, Bogden JD, Lavenhar MA, Bauman J W, Hirotsu T (1983) Na-K-ATP ase and potassium adaptation in the rat. Am J Physiol 244 : F105 - 111

Carl AB, Donald JL (1985) Cadmium and nickel in mainstream pariculates of cigarettes containing tobacco grown on a low-cadmium soil-sludge mixture. J Toxicol Environ Health 16 : 547 - 552

Carl AB,Charlotte MR, Dietrich H, John D A, Donald J L (1986) Cadmium in smoke particulate of Regular and filter cigarettes containing low and high cadmium concentrations. Bull Environ Contam Toxicol 36 : 372 - 375

Watanabe T, Kasahara M, Nakatsuka H, Ikeda M (1987) Cadmium and lead contents of cigarettes produced in various areas of the world. Sci Total Environ 66 : 29 - 37

Landsberger S, Larson S, Wu D (1993) Determination of airborne cadmium in environmental tobacco smoke by instrumental neutron activation analysis with a compton suppression system. Anal Chem 65 : 1506 - 1509

Rickert WS, Kaiserman MJ (1994) Levels of lead, cadmium, and mercury in Canadian cigarette tobacco as indicators of environmental change; Results from a 21-year study (1968-1988). Environ Sci Technol 28 : 924 - 927

Barry GM, Nicholas WL, David AP (1994) Vanadium uptake by higher plants: some recent developments. Environ Geochem and Health 8 : 14 - 18