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Chloroform in Tap Water and Human Blood

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Several investigations have suggested that the main source of chloroform found in human blood is tap water (US EPA 1978, Cotruvo 1980, Pfaffenberger et al. 1980, Pfaffenberger and Peoples 1982). The negative effects of chloroform in reversible kidney and liver injuries when used earlier as an anaesthetic agent in surgery are well documented, as well as liver anlargement, fat degeneration and toxic hepatitis caused by industrial exposure (Jones et al. 1985, Bombski et al. 1967). Chloroform has also been shown to be carcinogenic in animal experiments (NAS 1977). The fact that chloroform is formed during disinfection of water and also found in human serum (Pfaffenberger et al. 1980) and body fluids (Pfaffenberger and Peoples 1982, Dowty et al. 1975, Kroneld and Reunanen 1983) explains why a maximum concentration for total trihalomethane (the sum of the concentrations of chloroform, bromodichloromethane, dibromochloromethane and bromoform) in drinking water has been fixed in several countries. The World Health Organization has recommended a value below 30 ug/l for chloroform in drinking water.

The possible health risks to animals and humans exposed to volatile halocarbons or chloroform through drinking water make it important to study the occurrence in tap water and blood samples.

MATERIAL AND METHODS

Chloroform and other volatile halocarbons were analysed through elution with n-pentane (Kroneld and Reunanen 1983). The determinations in tap water were carried out by extracting 100 ml (22°C) of water with 5 ml of n-pentane containing the internal standard (400 ng/ml) for 5 minutes, and then injecting a 2 ul aliquot of the pentane phase into the gas chromatograph (GC) equipped with a split injector and a ^{63}Ni electron capture detector (ECD). A 1 ml portion of serum, plasma or blood cells was measured into a test tube, and

100 ul of n-pentane containing 100 ng/ml of 1-odobutane as an internal standard was added. After extraction and a short period of centrifugation at 1000 rpm, one 3 ul aliquot of the pentane phase was injected into the GC. A Schimadzu C-R1B integrator calculated the concentrations of identified compounds according to the sorted calibration data (figure 1). Masspectrometry was used to confirm the analyses on a few occasions.

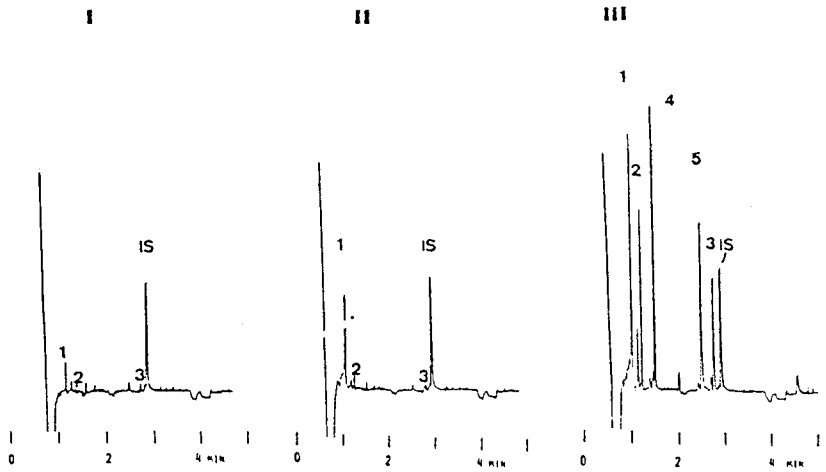

Figure 1. A chromatogram showing solvent impurities (I), an extract of 1.1 ml of blood (II) and an extract of blood plus added reference haloforms (III). 1=$CHCl_3$, 2=CCl_4, 3=Cl_2C = CCl_2, 4=$CHBrCl_2$, 5=$CHBr_2Cl$, IS=internal standard. Coloumn: SE-52, 20-m x 0.3-mm i. d; temperature: 50°C; carrier gas: 1.7 ml hydrogen/min.

Tap-water samples and well-water samples, used as controls were taken monthly during the study period. The blood samples were collected from controls, healthy individuals and patients (Table 1).

Table 1. The categories of samples

	Controls	Healthy individuals	Patients
n =	100	200	210
o =	40	75	95
o =	60	125	115
water source			
- chlorinated		+	+
- non-chlorinated	+		

The patients at the Turku University Central Hospital and at the Health Centres in Turku had medical problems including manig depression, tumours, heart diseases, diabetes, cirrhosis, ulcers and miscellaneous. The healthy individuals and the patients were served by chlorinated water, while the controls living in the archipelago of SW Finland used non-chlorinated water from wells. An interview held at the time of sampling elicited information regarding age, sex, work, disease, habitat, food and fluid ingestion or source of drinking water, smoking patterns. The aim during the sampling was to establish a basis for possible epidemiological evaluation, if the actual analyses could give such a reason. Possible contamination from exposure through industrial work and laboratories was avoided. The distribution between serum, plasma and cells was investigated by adding 50 ul test solution aliquots with known concentrations of volatile halocarbons tp. 1.1 ml blood samples free from interfering halocarbons.

RESULTS AND DISCUSSION

The determinations of chloroform are shown for tap water, well-water and in plasma and blood cell samples from healthy individuals, patients and controls in Table 2.

Of the volatile halocarbons only chloroform was found in blood samples from the healthy individuals and patients. The controls as well as the water samples from wells contained no compounds in this respect.

The chloroform concentration was significantly higher ($p < 0.001$) in all the monthly means in tap water compared to the minimum value found in January. There was also higher concentrations of chloroform in summer and autumn compared to early spring in this respect.

Only a few of the blood samples from healthy individuals and patients contained chloroform. About 4 % of the samples taken from healthy individuals during the research period (n=200) contained chloroform, at ranges of 20 to 25 nmol/l for plasma samples and 20 to 50 nmol/l for blood cell samples. Another 4 % of the total material contained traces of chloroform.

About 3 % of the samples taken from patients during the whole study (n=210) contained chloroform, 20 to 25 nmol/l for plasma samples and 20 to 55 nmol/l for blood cell samples. 3 % of the samples belonging to this category showed traces of chloroform.

The study of the bloos samples in Turku, with an exeption for the patients receiving haemodialysis

Table 2. Chloroform concentrations in water and blood samples.

month	I	II	III	IV	V	VI
tap water						
n = 12						
µg/l						
$CHCl_3$	11.7±0.3	19.1±0.2 p<0.001	18.2±0.3 p<0.001	34.2±0.4 p<0.001	47.1±0.4 p<0.001	50.2±0.4 p<0.001
healthy individuals						
nmol/l						
$CHCl_3$ plasma	25.1±4.6 (n=2)		21.2 (n=1)		20.6 (n=1)	
	+ (n=1)		+ (n=1)			+ (n=1)
	- (n=12)	- (n=17)	- (n=15)	- (n=16)	- (n=16)	- (n=15)
cells	35.1±14.9(n=2)		36.1 (n=1)		33.1 (n=1)	50.0 (n=1)
	+ (n=1)		+ (n=1)		+ (n=1)	
	- (n=12)	- (n=17)	- (n=15)	- (n=16)	- (n=16)	- (n=15)
patients						
nmol/l			23.5 (n=1)	25.0 (n=1)	22.8±2.1 (n=2)	
plasma	+ (n=1)		+ (n=1)	+ (n=1)	+ (n=2)	
$CHCl_3$	- (n=17)	- (n=17)	- (n=16)	- (n=14)	- (n=14)	- (n=17)
cells	33.2 (n=1)		32.1±10.5(n=2)	55.0 (n=1)	36.1±12.6(n=2)	
				+ (n=1)	+ (n=2)	
	- (n=17)	- (n=17)	- (n=16)	- (n=14)	- (n=14)	- (n=17)
well water						
n = 12						
µg/l						
$CHCl_3$	-	-	-	-	-	-
controls						
nmol/l						
$CHCl_3$ plasma	- (n=8)	- (n=9)	- (n=10)	- (n=8)	- (n=9)	- (n=10)
cells	- (n=8)	- (n=9)	- (n=10)	- (n=8)	- (n=9)	- (n=10)

+ = traces, - = not detected

VII	VIII	IX	X	XI	XII
$69.8^{\pm}0.6$ p<0.001	$72.4^{\pm}0.7$ p<0.001	$91.8^{\pm}0.6$ p<0.001	$103.3^{\pm}1.7$ p<0.001	$106.2^{\pm}1.2$ p<0.001	$58.4^{\pm}1.0$ p<0.001
		$23.3^{\pm}3.7$ (n=3)			
+ (n=1)					
- (n=13)	- (n=16)	- (n=12)	- (n=16)	- (n=16)	- (n=16)
		$38.3^{\pm}16.7$(n=3)			
+ (n=3)		+ (n=2)			
- (n=13)	- (n=16)	- (n=10)	- (n=16)	- (n=16)	- (n=16)
		21.1 (n=1)		20.7(n=1)	
			+ (n=1)		
- (n=17)	- (n=18)	- (n=16)	- (n=17)	- (n=15)	- (n=18)
		38.3 (n=1)		$41.6^{\pm}8.6$(n=3)	
			+ (n=3)		
- (n=17)	- (n=18)	- (n=16)	- (n=15)	- (n=15)	- (n=18)
-	-	-	-	-	-
- (n=8)	- (n=8)	- (n=8)	- (n=8)	- (n=8)	- (n=8)
- (n=8)	- (n=8)	- (n=8)	- (n=8)	- (n=8)	- (n=8)

therapy (Kroneld and Reunanen 1983), were spread over a two-year period, but no positive link could be found between water and blood concentrations of chlorform. Blood samples with chloroform were, however, not found during autumn, when the chloroform concentrations were highest in the water samples. This could mean that the blood concentrations came from other sources than water. The low concentrations of chloroform in general and the detection limits of the methods make it impossible to draw any further conclusions. The distribution between serum, plasma and blood cells was studied experimentally by adding a test solution containing a known amount of volatile halocarbons to blood samples (Table 3).

Table 3. Distribution of volatile halocarbons when added to blood in vitro.

Substance	added	determined	
nmol/l		serum, plasma	cells
$CHCl_3$	410.0	115.2±10.3 (n=15)	290.7±16.2 (n=15) $p < 0.001$
$CHClBr_2$	60.0	12.4±6.2 (n=14)	43.1±6.4 (n=14) $p < 0.001$
$CHBr_2Cl$	49.0	9.9±2.3 (n=13)	34.8±3.1 (n=13) $p < 0.001$

Higher concentrations ($p < 0.001$) were found in the cell fraction. The concentrations were about equal in serum and plasma and these concentrations could then be compared according to results in the literature. That volatile halocarbons are found in higher concentrations in the cell fraction makes it reasonable to use whole blood for extraction when studying volatile halocarbons in blood.

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