Factors Affecting the Amount of Mercury in Human Scalp Hair

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Hair samples collected from several socioeconomic and ethnic groups were analyzed for the amount of total mercury and methylmercury. Factors contributing to an increase in the amount of mercury in hair specimens are clarified.

Introduction

One of the most reliable methods for assessing mercury absorption is the measurement of mercurials in available biological specimens. Hair samples are useful for evaluation of the grade or type of exposure, because they are easy to take and the quantities of several substances detected in them give us quite valuable information in assessments of the health conditions of people.[1,2]

A greater amount of mercury has been found in the scalp hair of the Japanese than the Americans living either in Japan or in the United States.[3] This finding has been attributed to the abnormal exposure of the Japanese to mercurial pesticides used for agricultural purposes. Recent investigations to determine the amount of mercury in human scalp hair have suggested a positive correlation with the intake of mercurial compounds in foods. Several observations on the amount of mercurials in marine products also have been reported.[4,5] Consequently, arguments concerning the allowable concentration of mercury in foods have arisen.[6] Of course, there has been considerable evidence to show that several environmental factors contribute to the increase in the amount of mercury in human scalp hair. The available information on the contributing factors at the moment supports the local and systemic routes that reach the biological milieu of the human body. Occupational exposure, contamination by air pollution, and contamination by abnormal amounts of mercury in cosmetics and hair tonics are among the major sources of external contamination. On the other hand, mercury absorption may occur through ingestion of various food products contaminated with mercurials. Whatever the route, these mercurials are absorbed in the human body and are eliminated or excreted through biochemical channels by a systemic action.

Material and Method

Hair samples were collected from persons in several parts of the world to test the hypothesis that the amount of mercury in scalp hair is correlated with the amount of mercurials incorporated in foods. It is recognized that the consumption of fish and shellfish varies from country to country. According to a report by the Food and

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Agriculture Organization, the Japanese have the highest average consumption, 84 gm per day, Americans consume 17 gm per day and Pakistanis consume 5 gm per day. Hair samples were obtained from several groups of Japanese and a small group of Americans living in Japan. Some of the authors on assignments in various parts of the world collected the remaining samples. Results of epidemiological analysis of the amount of mercury in the following groups were previously reported[7]: (1) Japanese city dwellers who supposedly had no abnormal exposure to mercury compounds; (2) mostly fishermen and their families who ate more fish than ordinary Japanese; (3) hospital patients and almshouse residents who ate less fish than ordinary Japanese; (4) small groups of Americans; (5) residents of Silgarhi Doti and Dhangarhi, Nepal. One of the authors, on assignment there, observed that the Nepali people ate no fish at all during his 45-day stay.

In addition to the above mentioned observations, studies were made on scalp hair from the following groups:

1. Two groups of Indian people living in Bombay. One group consisted of vegetarians and the other of nonvegetarians. Vegetarians eat foods that come mostly from vegetable sources and nonvegetarians eat, additionally, foods of animal origin including several types of fish.

2. Workers in a molybdenum refinery shop in which they have been exposed during their working hours to mercury vapor from below 0.1 to 0.5 mg per cu m of air derived from the source which was used as a part of electrodes.

3. Minamata disease patients (13 males and nine females, six congenital patients included), 5 to 9.9 years after onset of the disease. The patients showed several characteristic symptoms.

All of the subjects except the Minamata patients were presumably healthy. Mercury workers showed neither tremor nor albuminuria. Hair samples were taken from the top of the head. To measure the total mercury in hair samples, the cold vapor atomic absorption method described by Jacobs, Yamaguchi, et al.[8,9] was used. Methylmercury was identified and determined by gas chromatography using an electron capture detector.[10]

Results

Consumption of fish varies from country to country because of dietary habits and availability of marine products. Table 1 presents values for various groups of Japanese as well as for some groups from other countries. Values for the inpatients of a psychiatric hospital who had

TABLE 1—International Comparison of Total Mercury Content of Scalp Hair

Nationality and Sex	Location	No. in Sample	Mean Mercury	Standard Deviation	*t*-test (*p*)	
A. Japanese male	Fukuoka, Kyushu	111	4.35	2.45		
B. Japanese female	Fukuoka, Kyushu	67	3.25	2.02		
C. Japanese male	Ikitsuki island	89	4.83	2.31		
D. Japanese male	Okinawa	10	4.56	1.71		
E. Japanese male	Psychiatric hospital	12	2.09	0.92	A:E	< 0.01
F. Japanese female	Psychiatric hospital	21	2.02	0.61	B:F	< 0.01
G. Japanese male	Almshouse	17	2.02	1.27	A:G	< 0.01
H. Japanese female	Almshouse	10	1.63	1.02	B:H	<0.01
I. American male	Kyushu	14	1.89	1.04	A:I	<0.001
J. American male	Cleveland, Ohio	3	2.41	1.32		
K. American female	Cleveland, Ohio	4	1.61	0.32		
L. Nepali male	Silgarhi Doti, Dhangarhi	31	0.163	0.187	A:L	< 0.001
M. Nepali female	Silgarhi Doti, Dhangarhi	14	0.457	0.484	B:M	< 0.001
N. Indian male	Nonvegetarian, Bombay	19	2.10	2.19		
O. Indian male	Vegetarian, Bombay	23	0.83	0.85	N:O	< 0.02

eaten less fish were significantly smaller than those who ate the usual amount of fish. No methylmercury was detected in the hair from Nepalese, who supposedly ate almost no fish. The amount of mercury in samples of vegetarians and nonvegetarians in India was compared (Table 2). The difference in mean values between the two groups was statistically significant.

A large amount of mercury in the hair of workers who were exposed to mercury vapor was detected (Table 3). However, the amount of methylmercury in them was almost in the normal range. This suggests the possibility that the abnormal amount of mercury found in hair samples (Nos. 12, 13, and 15) can be attributed to the mercurial contamination to which they have been exposed. On the other hand, a large amount of mercury was detected in the hair of Minamata patients (Table 4) and the ratio of methylmercury to total mercury in hair samples from this group was significantly larger than that in mercury workers

TABLE 2—Difference in Amount of Mercury in Scalp Hair of Vegetarians and Nonvegetarians in India

	Vegetarians			Nonvegetarians		
	Total mercury*	Methylmercury†	Ratio M/T‡	Total mercury*	Methylmercury†	Ratio M/T
			%			%
No. in sample	19	20		23	20	
Mean (ppm)	0.83	0.29	34.7	2.10	0.54	25.6
Median (ppm)	0.54	0.26		1.28	0.46	
Standard deviation (ppm)	0.85	0.10		2.19	0.38	

* Nonvegetarian versus vegetarian, $t = 2.56$, $p \leq 0.02$ (total Hg).

† Nonvegetarian versus vegetarian, $t = 2.87$, $p \leq 0.01$ (methyl Hg).

‡ M/T, methylmercury to total mercury (as Hg).

TABLE 3—Ratio of Methylmercury to Total Mercury in Hair of Molybdenum Refinery Workers

No.	Workshop	Total Mercury	Methylmercury		Ratio MMC Hg/Total Hg
			MMC	Hg	
		ppm			%
1	Bakeshop	3.77	1.53	1.22	32.4
2	Bakeshop	5.67	2.05	1.64	28.9
3	Bakeshop	4.46	2.22	1.77	39.6
4	Bakeshop	2.68	2.45	1.96	73.0
5	Bakeshop	6.09	1.49	1.19	19.5
6	Bakeshop	4.39	2.14	1.71	38.9
7	Bakeshop	3.94	1.85	1.48	37.5
8	Bakeshop	6.06	3.81	3.04	50.5
9	Bakeshop	8.15	3.53	2.82	34.6
10	Bakeshop	6.68	1.65	1.32	19.7
11	Bakeshop	9.77	2.65	2.12	21.7
12	Bakeshop	21.22*	1.26	1.10	4.8
13	Bakeshop	28.17*	2.45	1.96	7.0
14	Bakeshop	2.27	2.08	1.66	73.2
15	Bakeshop	19.53*	1.51	1.21	6.2
16	Electrolysis plant	5.39	0.93	0.74	13.8
17	Electrolysis	3.64	1.01	0.81	22.4
18	Bakeshop foreman	4.91	2.22	1.77	36.0
Mean		8.16	2.05	1.64	31.1

* Worked in a contaminated area with more than 0.1 mg per cu m^{Air}. (0.1 to 0.5 mg per cu m^{Air}). Other workers were in an environment with less than 0.1 mg per cu m^{Air}.

TABLE 4—Amount of Mercury in the Hair of Minamata Patients and Ratio of Methylmercury to Total Mercury

	Male					Female				
No.	Age	Years after onset	Total mercury	Methylmercury	Ratio*	Age	Years after onset	Total mercury	Methylmercury	Ratio
1	29	9.9	27.5			15	9.1	12.0		
2	16	9.8	24.5			16	9.0	32.5		
3	33	9.7	65.7	45.2	55.1	9†	8.9	11.6		
4	50	9.3	39.0			9†	8.8	9.0		
5	14	9.0	22.3			10	8.8	26.4		
6	41	9.0	17.8			20	8.8	25.0		
7	57	9.0	42.6			26	8.7	9.5		
8	35	8.9	18.3	5.3	24.1	53	8.7	34.5		
9	17	8.8	34.8	15.5	35.6	64	8.7	11.3	7.2	50.8
10	9†	8.7	5.9			12	8.7	23.3		
11	33	8.7	47.8			9†	8.7	5.9		
12	5†	5.0	12.7							
13	9†	5.9	12.7							
Mean	26.8	8.6	23.6	22.0	38.3	22.0	8.8	18.3		

* Ratio of methylmercury to total mercury (as Hg).
† Congenital Minamata patient.

who had heavy mercury exposure. This is evidence that the Minamata patients absorbed methylmercury by the gastrointestinal route through the ingestion of fish.

Discussion

It is well known that some marine products contain 40 to 90 per cent or more of methylmercury in the total mercury.[11] The metabolic transformation of mercury compounds in fish, if inorganic mercury is transformed into alkylmercury in the biological milieu, is a puzzle at the moment.

However, it is also true that the amount of mercury in a hair sample can be used in an assessment of mercury intake through food as well as a diagnostic criterion in mercury poisoning, particularly in alkylmercury poisoning.

In a previous report on the rate of increase of mercury content in the hair after the intravenous administration of alkylmercury compounds and other mercurials, it was concluded that the rate of increase was largest after the administration of alkylmercury compound. Arylmercury and mercuric chloride contributed almost nothing to the increase of mercury content in the hair of experimental animals.[12]

If the methylmercury is accumulated and concentrated through a food chain cycle, its occurrence and environmental sources, whether artificial or natural, should be determined.[13,14]

It is suggested in this report that the amount of fish consumed significantly influences the mercury content in scalp hair, particularly the methylmercury content.

Consequently, the actual or potential health hazards, particularly from a low levels of alkylmercury contained in marine products caught in a natural environment, urgently require further study.

The importance of determining the ratio of methylmercury to the total mercury in biological specimens for an assessment of mercury absorption is also emphasized. This means that the significance of the amount of mercury in hair specimens should not be evaluated merely by the total amount of mercury; determination of the ratio of methylmercury to total mercury is necessary.

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SPECIAL NOTICE

Bacterial Nitrate Reduction Test
Suggestions for Use of Alternate (Noncarcinogenic) Reagents

The Committee on Laboratory Standards and Practices of the American Public Health Association is concerned not only with the development and publication of Standard Methods volumes but is also interested in problems which will affect the use of these methods.

Recently one reagent which has widespread use in microbiological methods was placed on a list of carcinogenic chemicals published in the *Federal Register*. The chemical is α-naphthylamine and is used as a reagent in determining nitrate reduction in bacterial cultures. Although the concentration normally used is less than 1 per cent and, therefore, its use is not in violation of regulations, laboratories are experiencing increasing difficulty in finding a supply adequate for their needs.

The Committee on Laboratory Standards and Practices requested Dr. Albert Balows of the Center for Disease Control to investigate the possibilities of alternate satisfactory reagents. After approximately 8 months of investigative and comparative effort, Dr. Balows has reported that either

N,*N*-dimethyl-1-naphthylamine (DM-ANA)

or

Cleve's acid (5-amino-2-naphthylene sulfonic acid)

may be substituted for α-naphthylamine. The only noted difficulties with the two reagents were that color development appeared more slowly with DM-ANA and that color faded more rapidly with Cleve's acid. However, the level of sensitivity for detecting nitrite by both reagents was well below the amount produced by enteric bacteria.

In conclusion, the Committee on Laboratory Standards and Practices recommends that laboratories may wish to discontinue the use of α-naphthylamine by substituting either *N*,*N*-dimethyl-1-naphthylamine or 5-amino-2-naphthylene sulfonic acid for determining nitrate reduction by bacterial cultures. (*N*-(1-naphthyl)ethylene diamine hydrochloride continues to be the recommended reagent for testing nitrate reductions in mycobacterial cultures.) Of course, it should be emphasized that no laboratory should incorporate the use of either of these alternates until they have conducted appropriate comparative evaluations in their own diagnostic facility.

Committee on Laboratory Standards and Practices
American Public Health Association
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