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Factors influencing the total mercury and methyl mercury in the hair of the fishermen of Kuwait

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"Capsule": *Methyl mercury concentrations in human hair showed a positive correlation with fish consumed.*

Abstract

Total and methyl mercury (MeHg) levels in the hair of fishermen are described anticipating that they represent the critical group for dietary exposure. One-hundred human hair samples were collected from fishermen (Egyptians: age range 25–60), living in Doha Fishing Village, Kuwait. Thirty-five additional samples were taken from a control group working in a local construction company (age range 26–35). Overall mean concentrations in the hair of the population of fishermen are 4.181 ± 3.220 and 4.025 ± 3.130 μg g^{-1} for total and MeHg, respectively. The equivalent values for the control are 2.617 ± 1.404 and 2.556 ± 1.391 μg g^{-1} for total and MeHg, respectively. MeHg concentrations are strongly correlated to those of total Hg ($r = 0.999$, $p < 0.00005$) and MeHg concentrations in human hair are unrelated to age and duration of residence in Kuwait but show a positive correlation with the quantity of fish consumed. Levels of Hg in hair also show a tendency to increase in those who prefer to eat the entire fish, including the heads. In general, the concentrations of total and MeHg in fishermens' hair are twice the WHO 'normal' level (2.0 μg g^{-1}) but are still less than the WHO threshold level (10.0 μg g^{-1}). The results also show that grey hair contains undetectable amounts of Hg and therefore does not reflect individual exposure to this contaminant.

Keywords: Mercury; Methyl mercury; Human hair; Fishermen; Fish consumption

1. Introduction

Mercury (Hg) and its compounds are recognised as potentially hazardous material and are rated in the top category of environmental pollutants. The toxicity of Hg has caused widespread public human concern as a result of several widely publicised disasters (Lipfert et al., 1995). In many cultures the main source of human Hg intake is the consumption of fish and other marine animals. This has led to the introduction by several international organisations of upper limits for the daily intake of Hg from fish. The values for Hg in fish vary between 0.3 μg g^{-1} fresh weight set by US Environmental Protection Agency (EPA) (Gearhart et al., 1995), with not more than 66% in the form of organic Hg.

A number of workers have investigated the importance of fish as a source of exposure to Hg in the Arabian (Persian) Gulf region. For example, in an extensive International Atomic Energy Agency exercise during 1984–85 (ROPME, 1988) total Hg values in fish of the region were estimated to range between 0.007 μg g^{-1} (wet wt.) for Mediterranean amberjack (*Seriola dumerlii*) and 0.540 μg g^{-1} (wet wt.) in Karanteen sea bream (*Crenidens crenidens*) (ROPME, 1988). The overall mean value for different species was 0.158 ± 0.145 μg g^{-1} (wet wt.). In a subsequent exercise Al-Majed and Rajab (1998) reported Hg and methyl mercury (MeHg) levels in 105 samples of 23 different species. The levels of total Hg varied between 0.123 μg g^{-1} (dry wt.) in river shad (*Hilso ilisha*) of 450 g weight and 35 cm length to 4.500 μg g^{-1} in Indian flathead (*Platycephalus indicus*) of 1200 g weight and 47 cm length. The corresponding MeHg values were 0.015 and 3.862 μg g^{-1}, respectively. The overall mean concentrations for all the different species were 0.893 ± 0.799 μg g^{-1} and 0.711 ± 0.655 μg g^{-1} for total and MeHg, respectively.

Hg exposure in humans through seafood (fish) consumption has been studied by several workers. Data from several parts of the world indicate that relatively

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high levels of Hg can be found in exposed populations. The reference mean for total Hg in hair is 2.0 μg g^{-1} (IPCS, 1990).

Human exposure to Hg vapour in Kuwait was first studied by Zaki and Abdulraheem (1973) at the chlor-alkali plant which was in full operation at this time. Levels in air ranged from 0.3 μg m^{-3} recorded at the chlorine filling area to 566.6 μg m^{-3} recorded at the point in the middle of the Hg cell room. However, these workers did not record data on blood levels or human hair content of Hg. Among Kuwait residents, Bou-Olayan and Al-Yakoob (1994) reported mean Hg concentrations in hair of 4.05 ± 4.40 μg g^{-1} in 68 females and 5.52 ± 5.33 μg g^{-1} in 38 males. Samples represented individuals whose ages ranged from 2 to 57 years and results showed that 21% of them were above 6.0 μg g^{-1}. A selective summary of Hg in hair data is given in Table 1.

The present study assesses Hg levels in the hair of members of the fishing community in Kuwait who were predicted to represent a critical population for Hg exposure by the marine route. This study is a part of a comprehensive study of sources, distribution and transformation of Hg in the marine environment of Kuwait (Al-Majed, 1999).

2. Materials and methods

2.1. Sampling

Using clean stainless steel scissors, 100 hair samples were collected from fishermen living in Doha Fishing Village, Kuwait. Another 35 samples were taken from a control group working in a local construction company. The samples were taken from several sites of the scalp. The samples, 2–3 g each, were transferred to a polyethylene plastic sampling bag. Each bag was sealed, labelled and stored in a deep freezer until the time of analysis. The fishermen shave their heads once every 7–10 days, so the samples obtained represent approximately the same time period of hair production.

A questionnaire was completed for each volunteer in order to assess his (all were men) dietary habits. Their body weight and height were measured. They were asked about their age, nationality, occupation, the duration of their stay in Kuwait, smoking habits, health status with special reference to dental problems or the existence of amalgam filling as well as their dietary habits. Questions related to dietary habits included number of fish meals $week^{-1}$, quantity of fish $meal^{-1}$, source of fish, type of their favourite fish and the parts of fish usually eaten.

2.2. Sample preparation and analysis

Hair samples were cut into short segments and washed successively with acetone and water. Samples were separated by centrifugation and dried in a laminar flow hood (UNEP, 1987).

2.3. Analysis of total Hg

About 0.2 g of the dry sample was digested with 4 ml HNO_3 and 2 ml H_2SO_4, for 2 h at room temperature and 3 h at 90°C. The final determination was carried out using a PSA Hydride Vapor Generator connected to an Atomic Fluorescence Detector Model 10.023. A 20% $SnCl_2$ solution was used as a reducing agent and 1% HNO_3 solution was used as a blank. Argon was used as the carrier gas.

2.4. Analysis of MeHg

About 0.2 g of dry sample was analysed in accordance with the UNEP (1987) method. The final determination was carried out on an HP Gas Chromatograph Model 5890 Series II, equipped with glass column of 1.6 m length and 2 mm internal diameter, packed with 5% DEGS–PS (diethylene glycol succinate modified with phosphoric acid) on 100–120 mesh (Supelco) and an electron capture detector. Nitrogen was used as the carrier gas.

2.5. Quality control

2.5.1. Total Hg analysis

The accuracy of total Hg analysis was checked by running four samples of Sample Reference Material (SRM) with each batch of samples (set of 25 samples). Recovery varied between 94.6 and 98.9%. The results of analysis are shown in Table 2. Six blank samples were also run with each set. The results show undetectable levels of total Hg in all the analysed blank samples. In order to check the reproducibility of the analysis, 23% of the samples were analysed in triplicate and one SRM out of four was also treated in the same manner. The coefficient of variation was between 0.08 and 2.95%.

2.5.2. MeHg analysis

The accuracy of MeHg analysis was checked by running two SRMs with each batch of samples (set of eight samples). The recovery varied in the range 92.4–105.8%. The results of this analysis are shown in Table 2. Two blank samples were run with each set. The results show no detectable levels of MeHg. In order to check the reproducibility of the analysis, 18% of the samples were analysed in triplicate. The coefficient of variation was 0.40–4.01%.

3. Results and discussion

The questionnaire results showed that the fishermen were all Egyptian and were mostly young, with good

Table 1
Levels of mercury (Hg) in human hair from different populations

Location		No. of samples	Levels of Hg compounds (μg g^{-1})		Comments	Reference
Papua New Guinea			MeHg	15.5 (mean) 3.2–50.5 (range)	Heavy fish-consuming population	Kyle and Ghani, 1982
			MeHg	6.4 (mean) 0.62–25.7 (range)	Lower fish-consuming population	
			MeHg	2.4 (mean) 0.33–9.0 (range)	Control group	
Finland			T-Hg	4.9 (mean)	Middle age fish-eating population	Lodenius et al., 1983
Spain	Two Atlantic coastal areas		T-Hg	10.41 and 8.36 (mean)	Fishermen in two areas	Lopez-Artiguez et al., 1994
			MeHg	8.28 and 6.72 (mean)		
Kuwait		106	T-Hg	4.60 ± 4.80 (mean) 0.80–25.00 (range)	Kuwait residence age (2–57 years)	Bou-Olayan and Al-Yakoob, 1994
Papua New Guinea		134	T-Hg	21.9 (mean) 3.7–71.9 (range)	Fish-eating population	Abe et al., 1995
			T-Hg	0.75 (mean)	Control population	
Columbia	Southern Bolivar gold mining zone	219	T-Hg	5.23 ± 5.78 (mean)	Fishermen	Olivero et al., 1995
				2.38 ± 3.27 (mean) 2.40 ± 2.02 (mean) 1.33 ± 0.78 (mean)	Miners People of various activities Control samples	
Japan	Tokyo	133	T-Hg	2.08–36.5 (range)	Diseased volunteers	Ryozo, 1995
Florida	Everglades region	350	T-Hg	3.62 ± 3.00 (mean) 1.28–15.57 (range)	Consumption of fish rate One meal week^{-1}, age (2–81 years)	Fleming et al., 1995
Italy	Poticello and Favignana island	123	T-Hg	> 6.0	Fishermen	Valentino et al., 1995
Peru	Mancora	131	T-Hg	8.3 (mean) 1.20–30.0 (range)	Infant–mother pairs Fish-eating population	Marsh et al., 1995
Seychelles		1604	T-Hg	5.9–8.2 (range)	Fish-eating population	Cernichiari et al., 1995
Croatia	Vis island	92	T-Hg MeHg	1.3–12.9 (range) 1.1–10.8 (range)	Age (2–83 years)	Buzina et al., 1995
Brazil	Tapajos river gold mining areas	147	T-Hg	4.7–151 (range)	General population	Malm et al., 1995
Bangladesh	Cox's Bazar, Chttagon, Dhaka, Mymensingh, Khulna and Bogra	219	T-Hg	0.44 ± 0.19 (mean) 0.02–0.95 (range)	Age (13–69)	Holsbeek et al., 1996

(Table continued on next page)

Table 1 (*continued*)

Location		No. of samples	Levels of Hg compounds ($\mu g\ g^{-1}$)		Comments	Reference
Spain	Tarragona Province	233	T-Hg	0.77 (mean) 0.18–2.44 (range)	Children (6–16 years)	Batista et al., 1996
Denmark	Faroe island	1023	T-Hg	4.5 (mean)	Fish-eating population	Weihe et al., 1996

health. None of them had dental problems or amalgam fillings. Most of them (99%) smoke from 3 to 5 cigarettes day^{-1} with one individual smoking more than 20 cigarettes day^{-1}. They exhibited a relatively narrow range of body weight and height. There is no favourite type of fish, as they usually eat what is readily available from their daily catch. The amount of fish consumed was about 0.250 kg of fish meal^{-1} for 98% of the fishermen. The rest (2%) consume about 0.500 kg meal^{-1}. About 20% of them have confirmed eating fish heads along with the other parts of body.

The control group was also selected to be of Egyptian nationality. They were young and healthy and none of them had dental problems. They are also occasional smokers, not exceeding 5 cigarettes day^{-1}. There is no preference for a certain type of fish. Their source of fresh fish comes mainly from Fahaheel Fish Market in the southern area of Kuwait, since it is closer to their working area. The amount of fish consumed is about 0.250 kg of fish meal^{-1}. About 26% of this group acknowledged eating fish heads along with the other parts of the body. About 29% of this group do not eat fish, whereas the rest eat fish 1–2 times week^{-1}. Those who eat fish (34% of this group) confirmed that canned tuna fish represent at least half of their total fish intake. No significant difference was found between the two groups except that the fishermen were slightly older (mean age = 34.9 years) than the control group (mean age = 30.4 years). This was unavoidable because of the demographics of Egyptian workers in Kuwait that was radically changed as a consequence of the fighting and its aftermath in the early 1990s. However, the two groups were significantly different in their fish diet habits, i.e. frequency, quality and type of fish consumed.

3.1. Total and MeHg in hair samples

The results of the analyses of the fishermen and the control group are shown in Table 3 and in the form of histograms of the concentrations in Fig. 1. They follow what is essentially a log-normal distribution which was confirmed using a Kolmogorov–Smirnov test, though the hypothesis failed the Shapiro–Wilks test. Because the distribution is therefore only borderline classifiable as log-normal both arithmetic and geometric means are quoted for key results.

About 87% of the fishermen's samples exhibit total Hg concentrations within the range of $1.0\text{–}<6.0\ \mu g\ g^{-1}$ whereas for the control group about 80% of the samples are within the range of $\leqslant 1.0\text{–}\leqslant 4.0\ \mu g\ g^{-1}$. These results contrast with those previously reported by Bou-Olayan and Al-Yakoob (1994) who reported levels in the general population in Kuwait around twice those for the present control group. However, our results are consistent with those reported for other fishing communities as summarised in Table 1.

Table 2
Results of quality assurance procedures for total and methyl mercury (MeHg) analysis ($n = 7$ for total Hg and $n = 60$ for MeHg)

Standard Reference Material	Certified value (μg g^{-1})	Obtained mean (μg g^{-1})	Standard deviation	Coefficient of variation (%)	Recovery (%)
IAEA - 086 (total Hg)	0.57	0.564	0.012	2.2	98.9
IAEA - 086 (MeHg)	0.297	0.273	0.003	1.3	94.1
IAEA - 085 (total Hg)	23.007	21.919	0.139	0.6	95.3
IAEA - 085 (MeHg)	22.007	21.151	0.073	0.4	96.1
CRM - 397 (total Hg)	12.3 ± 0.57	11.637	0.068	0.6	94.6
GBW - 09101 (total Hg)	2.16 ± 0.217	2.131	0.028	1.3	98.7

The overall mean concentrations in the hair of the fishermen were 4.181 ± 3.220 (geometric mean 3.060) and 4.025 ± 3.130 (geometric mean 2.922) μg g^{-1} for total and MeHg, respectively. The overall mean concentrations in the control group were 2.617 ± 1.404 (geometric mean 2.225) and 2.556 ± 1.391 (geometric mean 2.160) μg g^{-1} for total and MeHg, respectively. The differences between the means for both groups were tested using *t*-test. Results indicated that the overall means for the two groups were significantly different ($p = 0.007$ and 0.009 for total Hg and MeHg, respectively).

In both groups there is a strong correlation between total and MeHg concentrations (Fig. 2) with MeHg representing 95.6 ± 3.9 and 97.1 ± 2.5% of the total for the fishermen and the control group, respectively (correlation coefficients in both cases are > 0.999). These results are consistent with those reported previously by, for example, Girard and Dumont (1995) and Richardson et al. (1995).

Forward multiple regressions were computed between total and MeHg concentrations and the various assessed variables (Table 4). The only positive results were between concentrations and weight for the study group and concentration and the number of fish meals for the control group.

3.1.1. *Hg concentrations and other parameters*

The levels of total and MeHg are also evaluated below in relation to the other variables addressed in the questionnaire, including the following.

3.1.1.1. Age. The age range of the fishermen was 16–58 years with a mean of 34.9 years. The relationships between Hg concentrations and age were tested by one-way analysis of variance (ANOVA) ($p = 0.656$ and 0.247 for total and MeHg, respectively). The results are shown in Fig. 3. No clear, statistically distinguishable trends are observable, though the mean concentrations of total Hg increases with age up to age 45 and decreases thereafter. The trend in MeHg concentrations is similar, though not identical, because in that case the youngest age category has a slightly higher mean concentration than the 26–30-years age group. The highest recorded mean values for total and MeHg are 5.328 ± 4.546 and 5.536 ± 4.682 μg g^{-1}, respectively, and are found in the group age 41–45 years, which represents 15% of the total. The lowest values for total and MeHg are 3.296 ± 2.138 and 3.181 ± 2.025 μg g^{-1} for the group age 51 ± 60 years, which represents 4% of the total samples.

In both cases the levels of Hg contamination are significantly higher than those in the control groups (Fig. 3). The control group had a narrower age distribution than that for the fishermen but similarly showed a small increase in contaminant burden with age.

The last two age groups of fishermen (46–50 and 51–60 years) show a slightly lower concentration of both total and MeHg which agrees with the findings of Nakagawa (1995) who found a significant decrease in total Hg in hair after 40 years of age in a study group of Japanese allergy sufferers. Buzina et al. (1995) also found that the Hg content of hair in subjects with MeHg above the provisional tolerable weekly intake (PTWI) does not increase significantly after the age of 35 years. However, Bou-Olayan and Al-Yakoob (1994) found a weak correlation between Hg contents and the age of the donor ($r = 0.44$) but these findings may have been influenced by not removing grey hairs from the samples before the analysis, as grey hairs have no Hg content (see below).

3.1.1.2. Hair colour. An examination of the relationship between hair colour and contaminant content is revealing (Fig. 4). In Fig. 4 grey and black hair from the same individuals are compared. Grey hair represented a significant (12%) proportion of the total number of samples with the age of fishermen with more than 40% of grey hair varying between 35 and 58 years old. The results show a notable elevation of contaminant levels in hair that is entirely black as opposed to partially grey hair. The mean total Hg and MeHg concentrations are 6.897 ± 5.299 and 5.523 ± 4.872 μg g^{-1}, respectively. A few samples of exclusively grey hair were analysed but had no detectable levels of total Hg; thus, it is difficult to compare young fishermen to relatively older ones without removing grey hairs from the samples before analysis.

The link between Hg content and hair colour is believed to result from the role of sulphur-containing

Table 3
Mercury (Hg) concentration data and other details from questionnaire responses for the fishermen and the control group

	Age (years)	Residence time (years)	Height (cm)	Weight (kg)	Fish meals per week	Part of fish consumed[a]	MeHg (mg g^{-1})	ΣHg (mg g^{-1})
Fishermen	45	6	175	70	14	2	4.011	4.484
	38	13	173	73	7	1	4.026	4.789
	24	2	168	66	7	2	3.578	3.856
	41	2	183	80	7	1	10.988	11.435
	43	11	175	78	21	1	10.520	10.849
	58	2	176	75	21	1	6.169	6.457
	45	6	184	85	21	1	17.214	17.788
	46	0	170	68	7	2	4.215	4.908
	46	14	175	80	21	1	9.784	10.116
	46	5	175	75	7	1	9.010	9.495
	35	2	175	76	21	2	5.465	6.092
	25	2	164	66	21	2	3.255	3.799
	35	0	166	66	21	2	0.019	0.025
	42	12	183	87	7	2	5.785	5.995
	35	1	170	68	7	2	1.579	1.717
	33	4	170	69	14	2	4.514	4.615
	35	15	170	70	7	2	3.258	3.362
	35	12	175	72	7	2	3.854	3.928
	27	0	170	70	7	2	1.699	1.833
	34	3	172	70	14	2	5.701	5.668
	26	0	178	74	14	2	4.601	4.700
	31	2	179	69	7	2	2.200	2.391
	32	2	175	69	7	2	3.157	3.294
	16	2	170	73	7	2	2.245	2.272
	30	2	170	73	21	2	2.598	2.640
	26	2	171	70	7	2	1.301	1.342
	30	0	170	74	7	2	1.520	1.552
	32	2	164	72	7	2	4.455	4.622
	45	17	164	76	7	1	7.593	7.805
	58	13	173	74	7	2	2.574	2.643
	26	6	170	73	7	2	5.977	6.111
	42	13	172	76	7	1	2.367	2.476
	38	15	180	88	7	1	1.496	1.619
	37	13	178	75	4	2	1.758	1.789
	50	13	175	67	4	3	2.241	2.484
	44	10	184	86	7	1	1.609	1.757
	28	1	188	80	7	2	1.178	1.239
	28	2	170	63	7	2	5.241	5.311
	36	13	170	67	4	2	2.706	2.794
	48	14	170	64	4	2	1.957	1.984
	45	15	163	66	4	2	2.478	2.697
	42	13	154	59	7	2	0.589	0.692
	23	1	173	70	7	1	2.257	2.404
	29	4	174	70	7	2	1.466	1.503
	33	8	170	75	7	2	0.712	0.750
	21	0	164	74	14	2	0.266	0.276
	42	3	170	73	7	2	3.743	3.810
	54	16	163	66	21	1	1.698	1.765
	50	18	170	68	4	1	0.387	0.408
	36	15	175	74	7	3	3.820	3.901
	49	0	175	70	7	2	0.467	0.480
	26	3	170	71	7	2	3.695	3.826
	44	11	164	86	7	2	3.378	3.451
	52	1	170	67	7	2	2.281	2.320
	27	3	175	76	7	2	4.000	4.086
	28	4	175	70	7	3	2.132	2.272
	46	15	166	62	7	2	2.466	2.564
	37	3	188	64	7	2	7.840	7.998
	31	0	170	75	7	2	4.875	5.081
	32	1	195	68	7	2	0.354	0.366
	25	0	170	67	7	2	2.379	2.477

Table 3 (*continued*)

	Age (years)	Residence time (years)	Height (cm)	Weight (kg)	Fish meals per week	Part of fish consumed[a]	MeHg (mg g^{-1})	ΣHg (mg g^{-1})
	28	1	171	64	4	2	5.271	5.288
	44	12	175	79	7	2	5.589	5.676
	27	5	180	75	7	1	2.200	2.296
	31	13	180	78	21	3	5.899	6.110
	43	0	175	70	7	2	2.601	2.628
	28	0	170	75	7	3	3.345	3.366
	28	0	170	73	7	2	1.732	1.746
	30	2	175	69	7	2	0.978	1.131
	45	6	190	75	4	3	1.462	1.502
	29	2	180	77	7	2	3.686	3.710
	31	6	182	75	7	2	4.559	4.568
	28	4	180	72	7	2	2.211	2.340
	37	2	190	70	7	1	3.899	4.083
	26	0	170	70	7	2	3.777	3.886
	30	5	168	63	7	2	2.797	3.006
	26	4	162	66	7	2	1.541	1.615
	26	1	180	79	7	2	5.269	5.314
	37	9	170	62	3	2	2.581	2.752
	46	4	168	64	7	3	4.025	4.214
	25	2	160	64	7	2	4.867	4.930
	40	8	187	61	7	2	2.921	2.965
	40	0	164	87	7	2	4.340	4.422
	35	0	160	92	3	2	11.580	11.863
	33	0	180	84	4	3	16.540	17.131
	34	0	183	62	7	2	1.522	1.616
	28	2	186	78	7	2	8.667	8.873
	37	0	190	71	7	2	1.967	2.162
	50	25	180	89	7	2	8.057	8.265
	25	1	180	76	7	1	4.059	4.208
	26	0	170	76	4	2	4.456	4.650
	32	3	180	82	7	2	7.199	7.241
	24	0	188	62	4	2	11.688	11.925
	28	3	175	78	7	2	3.544	3.753
	24	0	175	80	7	2	6.011	6.277
	26	0	170	71	7	1	2.955	2.992
	27	1	180	83	7	3	4.533	4.704
	24	0	170	66	7	2	0.331	0.359
	31	12	180	80	4	2	3.859	4.008
	40	15	188	84	21	1	5.242	5.345
Control group	28	3	170	68	1	2	2.350	2.455
	34	2	170	61	0	0	0.912	0.941
	34	1	170	72	1	2	2.369	2.478
	29	2	175	76	1	1	3.202	3.212
	32	2	175	83	2	1	5.104	5.214
	29	2	175	66	0	0	1.009	1.120
	32	3	177	67	0	0	0.730	0.745
	28	2	180	82	2	2	4.545	4.645
	28	3	180	83	2	2	4.884	4.981
	28	2	175	71	1	2	2.766	2.812
	30	3	180	75	0	0	0.789	0.846
	31	3	170	73	2	1	5.106	5.142
	29	2	170	70	0	0	1.002	1.111
	31	2	175	74	0	0	0.992	1.094
	32	2	175	75	2	2	2.957	2.978
	30	2	175	81	2	2	3.845	3.942
	26	3	173	78	0	0	1.109	1.131
	26	2	170	70	0	0	0.945	0.979
	30	3	175	75	2	1	3.438	3.542
	35	3	175	84	2	1	4.138	4.243
	33	3	180	82	2	2	4.120	4.216

(*Table 3 continued overleaf*)

Table 3 (*continued*)

	Age (years)	Residence time (years)	Height (cm)	Weight (kg)	Fish meals per week	Part of fish consumed[a]	MeHg (mg g^{-1})	ΣHg (mg g^{-1})
	34	2	180	80	2	1	4.589	4.676
	35	3	180	73	1	1	2.874	2.979
	29	2	175	78	1	1	3.101	3.112
	28	2	175	72	1	2	1.689	1.745
	30	3	170	68	1	2	2.083	2.101
	29	2	175	70	1	2	1.964	1.975
	32	3	180	77	1	2	1.974	1.997
	30	3	180	78	1	2	2.103	2.122
	27	3	180	77	0	0	0.802	0.844
	33	2	175	75	1	2	2.354	2.411
	32	3	175	74	1	2	2.467	2.497
	28	2	175	72	2	2	3.740	3.764
	28	2	175	70	1	1	2.671	2.769
	35	2	170	66	0	0	0.750	0.764

[a] 1, Muscle tissue only; 2, muscle and sometimes whole fish; 3, whole fish.

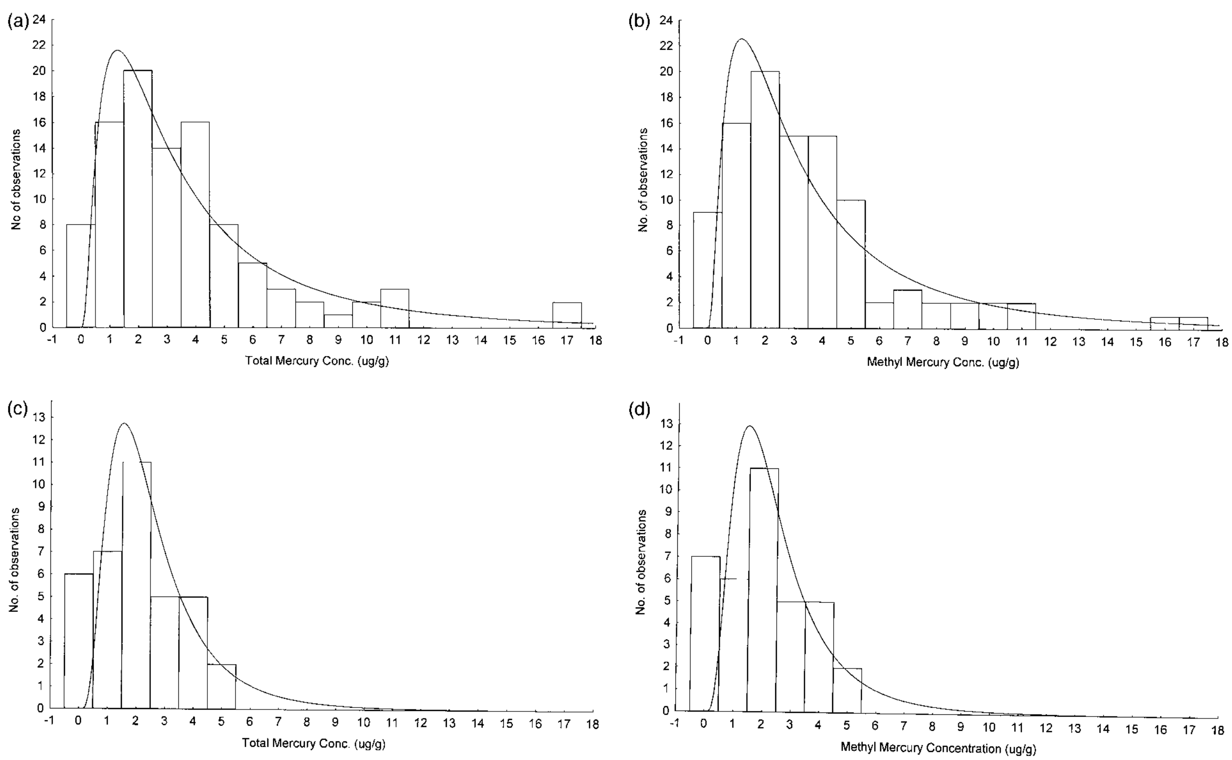

Fig. 1. Histograms of the mercury (Hg) concentration distribution within the hair of fishermen and the control population (a) total Hg—fishermen, (b) total Hg—control, (c) methyl mercury (MeHg)—fishermen, (d) MeHg—control.

chemicals in the formation of hair pigment, cysteine in particular.

3.1.1.3. Residence time in Kuwait. The fishing community in Kuwait has had a fairly rapid population turnover since the liberation and 23% of the fishermen have been in Kuwait for a period of <1 year and 47% for <2 years. However, as Takeo et al. (1986) have indicated Hg contamination levels in human hair can appear after a relatively short period of exposure (4 weeks). From Fig. 5 it can be seen that where comparable figures exist the concentrations in each residence group exceed the controls. Only in the fourth group (residence 5–6 years) are the mean and range markedly different, but this population represents only 8% of the total. It is noteworthy that those fishermen whose residence period in Kuwait include the period during and just after Iraqi occupation of Kuwait (1991) and the oil well fires have the highest mean and range of concentrations, possibly as a result of wide variations in additional exposure during this period. The longest residents would also presumably exhibit this phenomenon if it was not for the ‘grey hair’

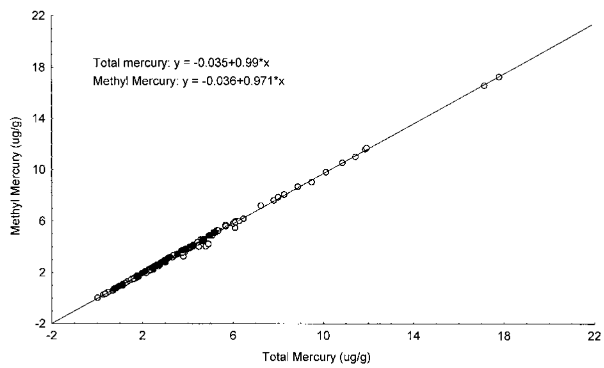

Fig. 2. The relationship between methyl mercury (MeHg) and total mercury (Hg) concentrations in the fishermen (○) and the control (●).

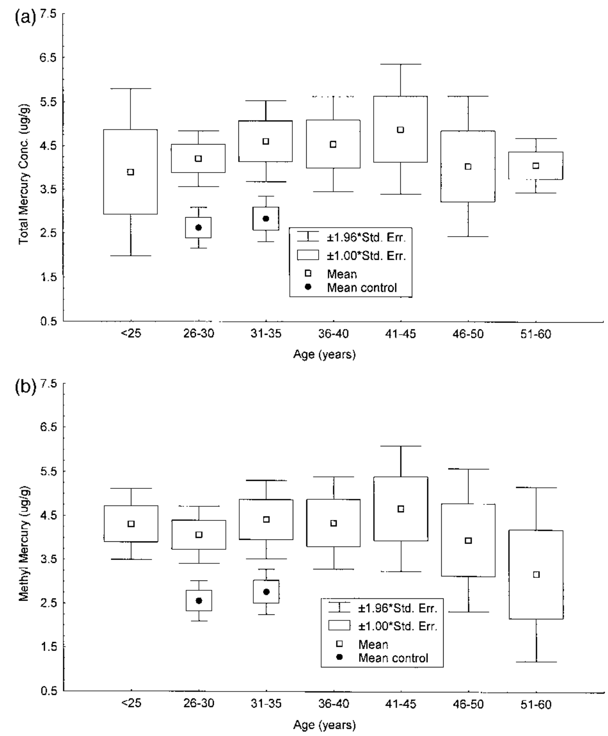

Fig. 3. (a) Total mercury (Hg) and (b) methyl mercury (MeHg) concentrations in fishermen and controls as a function of age.

effect noted above. Beyond that there is no significant relationship between the obtained levels of Hg and the duration of stay in Kuwait using one-way ANOVA ($p = 0.191$ and 0.283 for total and MeHg, respectively).

3.1.1.4. Body weight. Examination of the relationships between contaminant level and body weight give some indication that the two are related (Fig. 6). Where applicable the burden is higher in the fishermen than the control and both the mean and range of concentrations are greatest in the heaviest fishermen. It seems likely that body burden is related to body fat concentration rather than absolute weight but we do not have the necessary quantitative data to test this hypothesis.

3.1.1.5. Number of meals week^{-1}. Not surprisingly, fish form a significant part of the fishermen's diet and this is locally caught. Of the total number of fishermen, 70 eat fish ~7 times per week with the others exhibiting predominantly greater frequencies. The data are shown in Fig. 7. The data for the group representing the lowest fish eaters are abnormally high because of the presence of three individuals with particularly high (11.8–17.1 μg g^{-1} total Hg) concentrations. If these individuals are disregarded there is a noticeable increase of total and MeHg content with the increase in the number of meals per week. The highest mean values were therefore recorded for the group which has the highest consumption of fish and are 6.453 ± 4.976 and 6.169 ± 4.842 μg g^{-1} for total Hg and MeHg, respectively.

Of the control group about 29% do not eat fish and these individuals recorded the lowest mean value of total and MeHg, 0.958 ± 0.152 and 0.904 ± 0.129 μg g^{-1}

Table 4
Forward multiple regressions of concentration data for the fishermen and the control group

	Hg conc.	Log Hg conc.	MeHg conc.	Log MeHg conc.
Fishermen only				
Weight	0.418*	0.358*	0.422*	0.362*
Meals	0.131	−0.01	0.126	−0.02
Age	0.130	0.032	0.123	−0.028
Residence time	−0.14	–	−0.14	–
Edible parts	−0.03	–	−0.03	–
Control group				
Weight	0.102	0.073	0.098	0.067
Meals	1.02*	0.878*	1.02*	0.874*
Age	−0.02	−0.03	−0.02	−0.02
Residence time	−0.04	−0.06	−0.04	−0.5
Edible parts	−0.21	−0.046	−0.2	−0.059

* Result is significant at the 95% level.

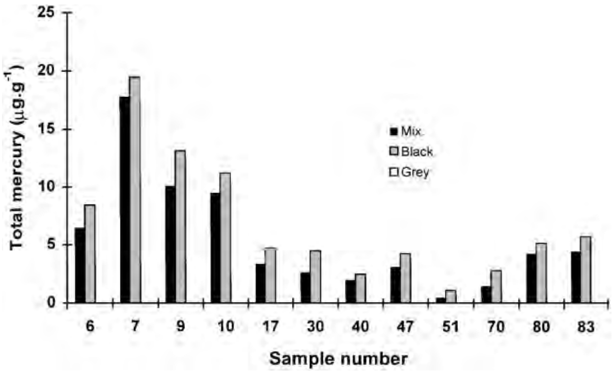

Fig. 4. The total mercury (Hg) concentration in fishermen's hair as a function of hair colour. Note that the levels were undetectable in grey hair.

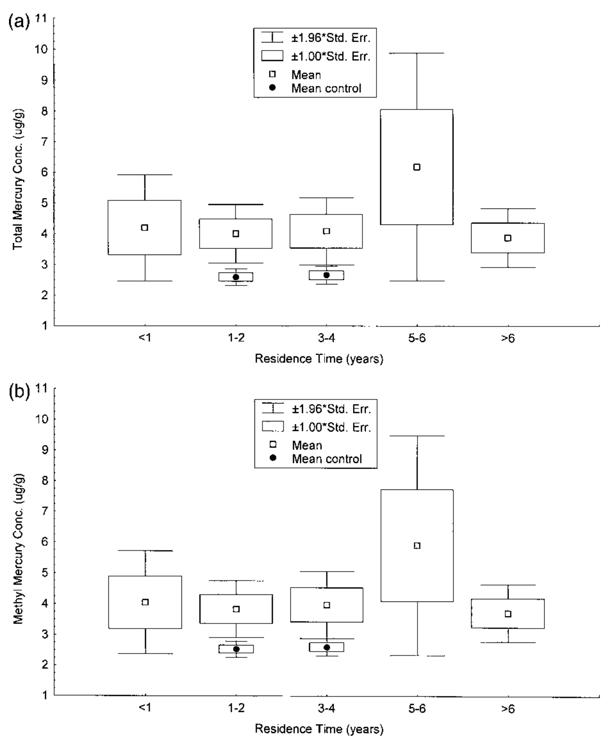

Fig. 5. (a) Total mercury (Hg) and (b) methyl mercury (MeHg) concentrations in fishermen and controls as a function of residence time.

respectively. Of the remainder, 40% of this group eat one fish meal week^{-1} and for them the mean values for total and MeHg are 2.476 ± 0.454 and 2.426 ± 0.450 µg g^{-1}, respectively. Of this group, two workers (14%) eat canned tuna fish once a week. The highest mean values of total Hg are 4.304 ± 0.708 µg g^{-1} and for MeHg is 4.224 ± 0.696 µg g^{-1} are recorded in group 3 (two meals week^{-1}). Of this group about 82% eat canned tuna fish once a week. In previously analysed canned tuna fish samples available in Kuwait and which derive from four different countries, the levels of total Hg range from 0.037 to 1.700 µg g^{-1} and the MeHg range was from 0.032 to 1.500 µg g^{-1} (Al-Majed, 1995).

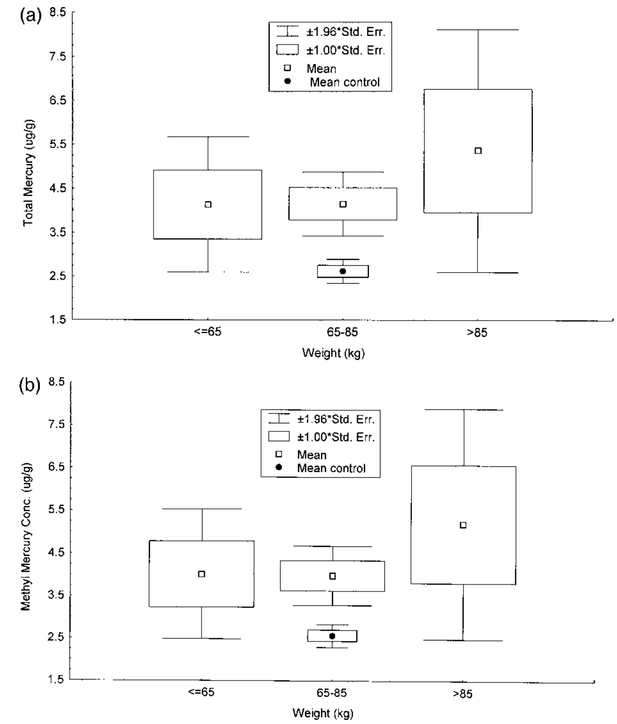

Fig. 6. (a) Total mercury (Hg) and (b) methyl mercury (MeHg) concentrations in fishermen and controls as a function of weight.

Overall it is not possible to distinguish between the control group and the low consumption fishermen. However, there is reasonably good evidence that there is a positive correlation between the fish consumption and the observed levels of total and MeHg. Such results agree with the those reported by Kyle and Ghani (1983), Abe et al. (1995) and Weihe et al. (1996).

3.1.1.6. Edible parts of fish. The fish consumption habits varied amongst the fishermen. Some normally only eating the muscle, some eating the muscle and head occasionally and the remainder who routinely eat the whole fish. The data for these three groups are shown in Fig. 8. The highest concentrations were obtained in the group which preferred to eat the whole fish including the head. This group represents 19% of the total sample. The lowest concentration was obtained in group 2 which normally eat just the muscle tissue. Those who ate fish occasionally with heads, shows an intermediate value (Fig. 8). Not only did group 2 have the lowest mean concentrations, they also have the smallest range.

The control group is divided into two groups (Fig. 8) according to their fish-eating habits. The highest concentration is obtained in the first group, which prefers to eat the whole fish including the head. For these consumers the total Hg is 3.877 ± 0.957 and 3.803 ± 0.952 µg g^{-1} for MeHg. This group represents about 26% of the total sample. The second group which

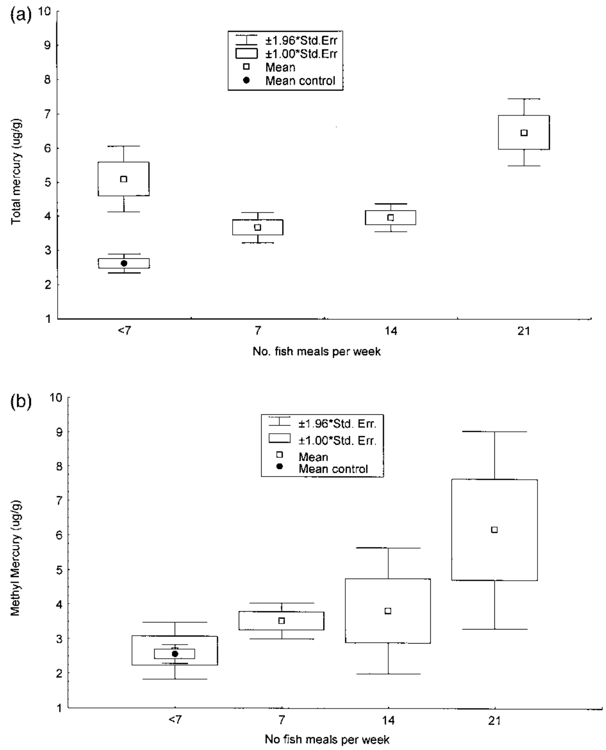

Fig. 7. (a) Total mercury (Hg) and (b) methyl mercury (MeHg) concentrations in fishermen and controls as a function of the number of fish meals consumed per week.

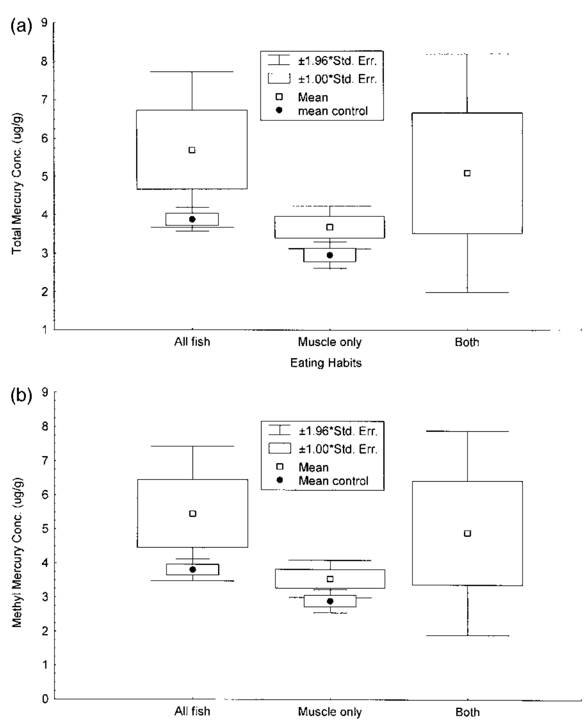

Fig. 8. (a) Total mercury (Hg) and (b) methyl mercury (MeHg) concentrations in fishermen and controls as a function of consumption preferences. All fish, routine consumption of complete fish; muscle only, routine consumption of fish muscle only; Both, mixed consumption of muscle and occasional whole fish.

prefers to eat fish without the head represents about 46% of the total samples. For them the total and MeHg concentrations are 2.945 ± 1.031 and 2.888 ± 1.011 μg g^{-1}, respectively. The rest of the sample (29%) are excluded from this comparison since they do not eat fish. It should be noted that the obtained levels of total and MeHg for the control population groups (eating whole fish and eating fish without the head) are slightly lower than their equivalent groups in the fishermen population.

The observed differences of contaminant burdens as a function of eating habits is not surprising because of the preferential association of Hg species with different organs. For example, Augier et al. (1993) have reported different concentrations of total Hg in different organs (liver, lung, kidney, muscle, heart and brain) of same species of fish and concluded that the brain and other fatty tissues containing the highest levels of Hg.

4. Conclusions

The levels of total and MeHg in the hair of about 78% of the fishermen and 63% of the control population exceeded 2.0 μg g^{-1}. In general, the mean concentrations of total and MeHg are around twice the WHO 'normal' level (2.0 μg g^{-1}) but are still less than the WHO threshold level (10.0 μg g^{-1}). However, it should be noted that levels are for fishermen who eat at least one meal of fresh fish per day, which is not the case for the general population. It may be added the health risk of eating fresh fish may be less than that associated with eating canned tuna fish. This is may be concluded by comparing those eating two meals per week of canned tuna fish (4.304 ± 0.708 and 4.224 ± 0.696 μg g^{-1} for total and MeHg, respectively) with those who eat seven meals of fresh fish per week (3.658 ± 2.271 and 3.522 ± 2.210 μg g^{-1} for total and MeHg, respectively).

In accordance to the obtained strong correlation between total and MeHg ($r = 0.999$), one of these determinations can be used for human hair samples to reflect the body content, and preferably the MeHg due to its higher toxicity (IPCS, 1990).

Total and MeHg concentrations in hair samples are found to be unrelated to age and the duration of residence in Kuwait for the Egyptian fishermen and the control group. A positive relationship is found between the fish intake quantity and with the edible parts of fish.

The results also show that grey hair do not correctly reflect the exact Hg content of hair. Thus, grey hair should be removed from samples before analysis. Other indicators for Hg exposure rather than hair analysis may need to be developed for people with grey hair.

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