

Results of the first pilot study on the chance of Italian seafood consumers
exceeding their individual allowable daily mercury intake

by

C.E. NAUEN, G. TOMASSI*, C.P. SANTARONI* and H. JOSUPETT
Fisheries Department, Food and Agriculture Organization of the United Nations,
Via delle Terme di Caracalla, 00100 Rome (Italy)
*Istituto Nazionale della Nutrizione, Via Ardeatina 546, 00179 Rome (Italy)

Resumé

Une enquête pilote fut conduite sur 3 sites côtiers italiens afin d'évaluer l'adsorption de Hg par les populations ayant une consommation de fruits de mer au-dessus de la moyenne, les fruits de mer étant la source majeure de mercure. L'échantillon était constitué de 638 personnes dans un groupe d'âge compris entre 0 et 85, des deux sexes. Ils appartenaient à 162 familles dont la moitié étaient des pêcheurs.

Les informations sur la consommation individuelle de fruits de mer pendant une période de 20 jours furent confrontées avec des données analytiques sur les niveaux de Hg dans les poissons et les espèces invertébrées. Au moyen de modèles de simulation sur les risques des consommateurs, le mercure absorbé a été estimé et comparé avec l'ingestion journalière couramment acceptable (acceptable daily intake, ADI).

Un haut pourcentage des personnes excédaient cette quantité (ADI), et parmi eux beaucoup d'enfants. Il est établi pour des populations humaines que le ADI correspond à 10% de la dose ingérée associée avec les premiers effets dans le groupe le plus sensible de la population adulte. Bien qu'excédant le ADI, tous les individus ont une ingestion se trouvant dans cette marge de sécurité.

Abstract

A pilot enquiry was carried out in three Italian coastal sites to assess the mercury intake in populations with an above-average seafood consumption, seafood being the major source of mercury. The panel comprised 638 subjects in the age range of between 0 and 85 years of both sexes. They pertained to 162 families, about half of which were fishermen's. Information on individual seafood consumption over a period of 20 days was matched with analytical data on mercury levels in the fish and invertebrate species. By means of a consumer risk simulation model, the estimated mercury intake was compared with the current acceptable daily intake (ADI).

A high percentage of the panelists exceeded their individual ADI, among whom were many children. The ADI established for human populations is 10% of the intake associated with the earliest effects in the most sensitive group in the adult population. Though exceeding their ADI, all panelists had an intake within this 10-fold "safety margin".

*
**

Introduction

The casualties of mercury poisoning after consumption of seafood contaminated by industrial discharge in Japan in 1953 - 1960 in Minamata and again in 1964 - 1965 in Niigata, stirred up considerable public concern (see DOI and UI, 1975; TSUBAKI and IRUKAYAMA, 1977). Even more dramatic were the outbreaks of methylmercury poisoning in Iraq in 1956, 1960 and 1971, when treated seed grain was used for the preparation of homemade bread (CLARKSON *et al.*, 1976; for health effects see GATTI *et al.*, 1979; PIOTROWSKI and INSKIP, 1981).

This triggered an ever-increasing number of investigations on levels of total mercury and methylmercury in foodstuffs, in freshwater and marine organisms, in seabirds (WESTOO, 1969; JERNELOV and LANN, 1971; SUZUKI *et al.*, 1980; AKIELASZEK and HAINES, 1981; RAMOS *et al.*, 1979; BACCI and RENZONI, 1973; STOEPLER *et al.*, 1979; DENTON and BRECK, 1981; RATKOWSKI *et al.*, 1975; ESTABLIER, 1973; GILLES *et al.*, 1974; GOCHFELD, 1980; review by HOLDEN, 1973). It became quite clear that, disregarding occupational exposure and poisoning from treated seeds not meant for human consumption, the principal way of human mercury intake is via consumption of seafood and exposed freshwater fish (WESTOO, 1969; BACCI *et al.*, 1976; PACCAGNELLA and PRATI, 1974; CLEMENTE *et al.*, 1977 and MARIANI *et al.*, 1980, produce indirect evidence in their comparison of dietary mercury intake between population groups in the cinnabar-rich Monte Amiata region and "controls" in Italian sites unexposed to mercury). The dominant part (in fact up to 100%) is the more poisonous methylmercury (for an overview see Working Group on Mercury in Fish, Australia, 1980). This made a number of governments impose legal action levels of fishery products locally caught and/or imported and marketed (Working Group on Mercury in Fish, Australia, 1980). Likewise, in view of often high mercury levels in certain species such as swordfish and tuna (PETERSON *et al.*, 1973; BECKETT and FREEMAN, 1974; ARIMA and UMEMOTO, 1976; OFFICER and RYTHER, 1981), national authorities set up expert panels to investigate the extent of the mercury problem in their country (Swedish Expert Group, 1971; NOAA/NMFS, 1978 WHEATLEY *et al.*, 1979; Working Group on Mercury in Fish, Australia, 1980).

While at first glance legal action levels are an attractive management tool, they suffer from serious disadvantages and might even create new problems:

- Enforcement requires an expensive market surveillance system to withdraw from the market a reasonably high percentage of fish not complying with the legal limit and the capacity to control the country's fishing operations for certain areas, species or sizes of fish, should sections of the national fish production exceed the action level.
- Inasmuch as industrial mercury discharge is the major source of contamination in some areas, the establishment only of such action levels in edible aquatic organisms might well ruin a fishery but would not necessarily exert pressure towards a maximum control of the industry since straightforward losses in fish tend to be quite inferior to any claims by industry.
- Action levels varying from one country to the other erect barriers and result in additional cost on both the exporter's and the importer's side.
- Individuals with easy direct access to the resources will not be protected.
- They are an indirect tool since they do not apply to the human mercury intake, which is a function of seafood consumption and mercury levels in fish.

Thus, to decide on any management scheme or modification of existing ones, the extent of the problems needs to be assessed, or, in other words, unless the scale of the mercury problem is known, proper counter-action cannot be taken. It obviously makes quite a difference whether a small community of, say, the Carloforte size (see PACCAGNELLA *et al.*, 1974) or larger segments of a national population are at risk.

Mercury levels in fish tend to be higher in the Mediterranean as compared to other seas (THIBAUD, 1971; CUMONT *et al.*, 1975; BERNHARD, 1978; FAO MED POL II, 1980) a finding that might be associated with the mercury anomaly in the Mediterranean basin, where 65% of world resources and about 50% of world extraction activities are located (BRINCK and VAN WANBEKE, 1974) and where weathering and above-average seismic activity release mercury to the atmosphere that will find its way to the aquatic environment and eventually its organisms. That is why we selected Italy for our pilot study to estimate the chance of seafood consumers exceeding their individual allowable daily mercury intake.

Several previous studies tackled the question from the human health point of view, laying emphasis on the analyses of mercury in hair and/or blood of fish-eating subjects; the reluctance of individuals to participate in such exercises, and the cost and infrastructure requirements, however, reduce their coverage to relatively few subjects (GRAS and MONDAIN, 1980; BACCI *et al.*, 1976; PACCAGNELLA and PRATI, 1974; ASTIER-DUMAS and CUMONT, 1975), while we attempted to record fish consumption more specifically and have a broader participation.

Outline of the pilot study

Two sets of data were required to estimate mercury intake: the individual consumption of seafood in a given period of time and the body burden of mercury in such organisms. The latter, or first data base, is founded to a great extent on data collected and quality-assessed within the framework of the FAO(GFCM)/UNEP Co-ordinated Pilot Project, Baseline Studies and Monitoring of Heavy Metals, particularly MED II, in which some 32 institutes all around the Mediterranean participated. Out of a total of 5,875 data lines, 4,672 are based on MED II. Due to the very nature of the project its main effort was directed towards analysis of mercury in four mandatory species standing for certain ecotopes: the bluefin tuna (Thunnus thynnus thynnus) or the swordfish (Xiphias gladius) as representatives of the pelagic migratory species and predators high up in the food-chain; the striped mullet (Mullus barbatus or, in some areas, Mullus surmuletus) as the exponent of small coastal fish, feeding mostly on benthic invertebrates and rather less migratory, and the Mediterranean blue mussel (Mytilus galloprovincialis) for sessile filter-feeding organisms likely to reflect most closely the local situation. Many institutes sampled and analysed additional species but in reduced number. It is here assumed that the mercury levels encountered in the specimens analysed do not differ significantly from those in seafood in the market place, even though there might have been an inherent tendency in the MED POL project to sample particularly polluted areas. However, clean "reference stations" were also sampled, and the resulting distribution of contaminant levels is not bimodal.

A great amount of analytical data on locally-commercialized fish and invertebrate species was additionally accessed in the files of the Italian Ministry of Health with reference to market samples processed by the respective Health Service and Veterinary Laboratories (Ministero della Sanità, pers. comm.). Finally, we drew upon data published in the scientific literature that were not submitted to the MED II pilot project (CAVIGLIA and CUGURRA, 1978; MARINI *et al.*, 1978; MAJORI *et al.*, 1978; MAJORI *et al.*, 1978a; PERNA *et al.*, 1971; YANNAI and SACHS, 1978). The majority are data on mercury in fish from the market; trout data, however, stem from fish sampled in an area particularly rich in cinnabar bedrock and thus average too high even though freshwater fish tend to have elevated levels. These data were therefore optionally substituted by trout data from the USA (NOAA/NMFS, 1980). In the context of this study 95% of mercury was assumed to be methylmercury (see, for instance, BACCI *et al.*, 1976, Working Group on Mercury in Fish, Australia, 1980).

The total of data lines derived from sources other than MED II was 1,203. Several of these were mean values from many individual determinations rather than single analyses, as was mostly the case in MED II. Thus, in order to avoid a bias, the data were weighted with respect to the number of samples they were based on.

The geographical distribution of the information on mercury in seafood was coded according to that adopted for the catch and landing statistics by FAO's General Fisheries Council for the Mediterranean.

The second data base had to be created by us on the basis of a pilot enquiry on seafood consumption since the regular nutritional surveys are not specific enough in distinguishing fish (at best categorized as shellfish, finfish, fresh, frozen and canned, but not breaking these down into species). Mercury levels in species, however, vary considerably (see Table 3). On the basis of an average per caput fish consumption in Italy of 12.5 kg per year in terms of live weight (Standardized Food Balance Sheets, FAO, Rome, Fisheries Department, Policy and Planning Division, unpubl.) and the assumption of fish consumption being relative to the composition of supply on the national market (FAO, 1981; GFCM/CGPM, 1980) the average daily mercury intake would be estimated at 7.8 µg per person. This value might serve as an indication that the Italian population in general can be considered not at risk of exceeding the FAO/WHO established provisional tolerable weekly intake (PTWI) (WHO, 1976) equivalent to a daily intake of about 28.6 µg of methylmercury for a "standard person" weighing 70 kg. This holds at least for the adult population. However, there are groups of the population, particularly those with easy access to the resource, that will have an above-average consumption. Among these one might expect:

- fishermen and their families,
- workers in fish processing plants and their families,
- fish vendors and their families,
- people living in coastal villages, particularly those with fish landing places,
- people near "hot spot" areas of pollution (i.e. chloralkali plants).

Consequently, our pilot study was directed towards such individuals or population groups whom we assumed to have an elevated seafood consumption, preferably of Mediterranean fish and shellfish. As a first step we intended to establish whether such subjects could be identified and, if so, what would be their percentage within the "easy-access" group. In this phase, due to the limited resources at our disposal, no attention was paid to the representativeness of the panel thus selected for any social stratum in Italy.

Table 1. Factors to break down the family meal calculated from energy requirements by sex and age groups

Age (years)	Male	Female
1 - 6	0.51	0.51
7 - 12	0.76	0.74
13 - 19	0.98	0.82
20 - 49	1.00	0.72
50 - 69	0.87	0.63
≥ 70	0.72	0.52

Table 2. Factors to break down the family meal calculated from average size in the US by sex and age groups

Age (years)	Male	Female
1 - 5	0.42	0.42
6 - 11	0.60	0.60
12 - 17	0.83	0.63
18 - 54	1.00	0.79
55 - 75	1.01	0.82
> 75	1.14	0.88

Within 162 families, a total of 638 individuals between 0 and 85 years of age of both sexes had their seafood consumption reported during each of the meals for 20 days. Out of this total, 302 were females and 336 males.

Contacts were established with the help of fishermen's co-operatives and local medical doctors. With the assistance of these generally trusted persons, a high percentage of families approached eventually participated in the enquiry, major difficulties being faced only in Fiumicino. Usually, a first interview was made in the presence of a resident in the area helping in the study to overcome the initial diffidence towards potential abuse for tax purposes of information gathered. In this interview the scope of the study was laid out, and the mode of filling the questionnaires left with the family explained. On this occasion, some socio-economic background data were asked, plus information on dietary habits. Whenever possible, the local assistant would later return to help fill in the questionnaire before collection at the end of the sampling period. This period extended from early February through March 1980 in Marina di Ravenna, from 8 March to 20 May in Fiumicino, and from 10 June through 12 July in Bagnara Calabra. About half of the families were fishermen's. When feasible, fishermen were asked to fill the questionnaires while on board.

During the enquiry at Ravenna, due to a nationwide strike of fishermen, fish was not as abundant on the market as usual. According to estimates of locals this further depressed availability of fish, anyway tending to be lower during winter due to adverse meteorological conditions.

Consumer-risk simulation model

The two sets of data mentioned above are suitably interrelated in a consumer-risk simulation model estimating the individual mercury intake from a given seafood consumption. This model has been developed by the US NMFS in response to the Food and Drug Administration's Federal Register Notice on mercury (NOAA/NMFS, 1978) and has been kindly made accessible to us to be adapted and run on the IBM system of FAO's Fishery Information, Data and Statistics Service. (Detailed information on the original version of the model is included in NOAA/NMFS, 1980).

The first module contains information on species of fish, area and month of sampling, weight, number of analyses and contaminant level per unit wet weight. Contaminant data in each species are represented by a lognormal distribution. In this module the mercury levels in every single fish sample are compared with the legal action level, the ones complying being automatically considered for the calculation of the average for a given species or group of species. The samples with mercury levels exceeding the action level are picked out by means of a random number generator, for consideration in average calculation or discarded in relation to the enforcement level to portray the efficiency of market control systems identifying and eliminating unfit commodities. Should there be marked differences, species can be considered by region or by season to simulate intake as closely as possible. In those species in which a correlation between size (weight) and mercury level is known to exist, this can also be accounted for. In case of insufficient data or under-representation of a species in the analyses, as compared to its share in the landings, the model provides for substitution of one species by another or a mixture of several other species. This was used in cases of less than 20 records per species, the whiting (*Merlangius merlangus*), for instance, was substituted by a species mix of whiting (8%), European hake (*Merluccius merluccius*, 60%), poutassou (*Micromesistius poutassou*, 30%) and unspecified gadoids (2%).

Table III

Mercury levels, edible part and relative importance of species consumed during the enquiry

Mercury content in edible part of species (mg/kg fresh weight = ppm)			Edible part (in % of total fresh weight or of commodity on the market)	Species (scientific name)	Relative importance of species among panelists during the enquiry expressed as consumption (edible part) per person and meal in grams. Frequency of meals (over a 20-day period) in brackets		
Number of records on file	$\bar{x}$	S.D.			Ravenna	Fiumicino	Bagnara
86	² 0.05	0.05	³ 70	<i>Alburnus alburnus</i>	117.33 (3)		
51	¹ 0.17	0.17	⁵ 90	<i>Anguilla anguilla</i>	191.19 (32)	115.96 (28)	
10 468	¹ 0.30	0.41	³ 20	<i>Aporrhais pes pelicani</i>	39.67 (3)		30.80 (10)
3 567	¹ 0.35	0.62	³ 80	<i>Argyrosoma regium</i>	160.00 (2)		
162	¹ 0.16	0.12	³ 70	<i>Arnoglossus laterna</i>	182.83 (12)		
54	¹ 0.11	0.01	⁴ 100	<i>Atherina hepsetus</i>		222.00 (2)	130.55 (33)
2 651	¹ 0.70	0.89	³ 80	<i>Auris thazard</i>			104.00 (20)
147	0.17	0.09	⁴ 90	<i>Boops</i> sp.			126.27 (97)
61	1.38	0.91	³ 30	<i>Callinectes sapidus</i>	95.67 (18)	40.29 (7)	
10 468	¹ 0.30	0.41	⁷ 15	<i>Chlamys</i> sp.		37.50 (4)	17.77 (26)
33	¹ 0.24	0.13	⁴ 65	<i>Dentex dentex</i>		162.50 (4)	
74	¹ 0.22	0.09	⁴ 54	<i>Dicentrarchus labrax</i>	161.80 (5)	101.71 (153)	61.85 (13)
60	0.09	0.05	³ 50	<i>Diplodus</i> sp.	120.06 (52)	62.41 (17)	
365	0.39	0.33	³ 15	<i>Donax trunculus</i>		17.63 (38)	
1 426	¹ 0.14	0.07	⁴ 75	<i>Engraulis encrasicolus</i>	99.38 (45)	107.64 (14)	115.90 (103)
74	¹ 0.22	0.09	⁴ 68	<i>Epinephelus guaza</i>		204.00 (8)	
2 651	¹ 0.70	0.89	³ 70	<i>Euthynnus alletteratus</i>			99.71 (7)
4 746	0.24	0.39	³ 85	<i>Gymnamodytes</i> sp.		66.00 (1)	40.33 (6)
529	¹ 0.67	0.54	³ 70	<i>Hexanchus griseus</i>			70.00 (4)
1 009	¹ 0.85	0.60	³ 45	<i>Homarus gammarus</i>	82.00 (2)		
4 319	¹ 0.37	0.62	³ 80	<i>Lepidopus caudatus</i>		78.00 (1)	141.06 (115)

¹ Species had less than 20 contaminant-level-records and was substituted by species mix

continued

² Mean, standard deviation and number of samples taken from NOAA/NMFS (1980)³ Source: FAO, Fishery Industries Division (pers.comm.)⁴ Carnovale and Miuccio (1979)⁵ Horne and Birnie (1970)⁶ Zaitsev et al. (1969)⁷ Waterman, n.d.⁸ Hardy and Smith (1970)⁹ Torry Research Station, n.d.

Table III (continued)

Mercury content in edible part of species (mg/kg fresh weight = ppm)			Edible part (in % of total fresh weight or of commodity on the market)	Species (scientific name)	Relative importance of species among panelists during the enquiry expressed as consumption (edible part) per person and meal in grams. Frequency of meals (over a 20-day period) in brackets		
Number of records on file	$\bar{x}$	S.D.			Ravenna	Fiumicino	Bagnara
603	¹ 0.21	0.10	³ 70	<i>Lithognathus mormyrus</i>	103.67 (9)		
50	0.14	0.04	⁴ 65	<i>Loligo</i> sp.	105.81 (47)	104.25 (68)	71.36 (176)
62	0.17	0.09	³ 70	<i>Maena</i> sp.			96.29 (269)
319	¹ 0.25	0.27	³ 70	<i>Merlangius merlangus</i>	171.90 (69)		121.54 (220)
273	¹ 0.33	0.32	³ 70	<i>Merluccius merluccius</i>	117.50 (8)	139.73 (532)	94.49 (68)
319	¹ 0.25	0.27	³ 65	<i>Micromesistius poutassou</i>	131.53 (17)	122.31 (88)	61.40 (10)
4 746	¹ 0.24	0.38	³ 90	<i>Mola mola</i>			163.50 (6)
61	0.08	0.03	³ 64	<i>Mugil cephalus</i>	152.37 (91)	117.24 (37)	58.50 (2)
137	0.12	0.35	³ 60	<i>Mugil</i> sp.			31.20 (5)
7 702	0.20	0.41	⁴ 32	<i>Mytilus</i> sp.	136.82 (109)	76.93 (15)	76.11 (132)
999	0.85	0.60	³ 28	<i>Nephrops norvegicus</i>	35.00 (5)	108.75 (4)	
603	¹ 0.19	0.12	³ 65	<i>Oblada melanura</i>			87.60 (10)
46	0.18	0.15	³ 90	<i>Octopus</i> sp.	92.54 (13)	156.25 (137)	113.22 (117)
603	¹ 0.18	0.12	⁴ 70	<i>Pagrus pagrus</i>			89.79 (28)
512	0.35	0.25	³ 45	<i>Parapenaeus longirostris</i>	69.92 (13)	65.04 (135)	54.88 (76)
155	1.71	0.94	³ 20	<i>Patella</i> sp.			5.00 (2)
83	0.15	0.14	³ 45	<i>Penaeus kerathurus</i>		65.71 (24)	
37	0.32	0.12	³ 60	<i>Platichthys flesus</i>	71.07 (14)		
162	¹ 0.16	0.16	⁴ 55	<i>Pssetta maxima</i>	91.33 (3)	154.20 (5)	
28	¹ 0.18	0.08	⁴ 35	<i>Raja asterias</i>		210.00 (3)	
806	² 0.05	0.04	³ 90	<i>Salmo salar</i>	45.25 (4)	74.83 (6)	
456	² 0.35	0.20	³ 68	<i>Salmo trutta</i>	204.25 (4)		
131	0.19	0.08	⁴ 70	<i>Sardina pilchardus</i>	140.80 (122)	139.97 (271)	103.54 (554)
81	0.27	0.12	⁴ 80	<i>Scomber</i> sp.		128.30 (23)	
2 879	¹ 0.35	0.42	⁶ 75	<i>Scomberesox saurus</i>			102.63 (83)
44	0.27	0.06	³ 60	<i>Scorpaena</i> sp.	82.33 (9)	172.14 (7)	70.16 (39)
695	¹ 0.58	0.43	³ 55	<i>Scyllorhinus canicula</i>	82.33 (6)		92.00 (6)
73	¹ 0.73	0.92	³ 25	<i>Scyllarus arctus</i>		2.00 (2)	
95	0.16	0.12	⁴ 50	<i>Sepia officinalis</i>	88.87 (86)	93.36 (121)	58.06 (193)
88	0.11	0.08	⁴ 48	<i>Solea vulgaris</i>	81.80 (84)	78.88 (122)	58.67 (9)
603	¹ 0.18	0.12	⁴ 69	<i>Sparus</i> sp.		92.05 (21)	

continued

Table III (continued)

Mercury content in edible part of species (mg/kg fresh weight = ppm)			Edible part (in % of total fresh weight or of commodity on the market)	Species (scientific name)	Relative importance of species among panelists during the enquiry expressed as consumption (edible part) per person and meal in grams. Frequency of meals (over a 20-day period) in brackets		
Number of records on file	$\bar{x}$	S.D.			Ravenna	Fiumicino	Bagnara
10 468	¹ 0.34	0.51	⁷ 23	<i>Sphaeronassa mutabilis</i>	38.25 (20)	69.08 (24)	
20	0.09	0.02	³ 85	<i>Sprattus sprattus</i>	189.85 (152)	175.91 (35)	
56	0.17	0.11	³ 40	<i>Squilla mantis</i>	115.21 (147)	89.21 (109)	
68	0.41	0.58	⁴ 90	<i>Thunnus alalunga</i>			117.43 (367)
1 518	¹ 0.64	0.63	⁴ 90	<i>Thunnus thynnus</i> (fresh)	40.99 (105)	42.25 (63)	88.11 (19)
68	¹ 0.13	0.08	³ 90	<i>Todarodes sagittatus</i>			119.23 (22)
695	¹ 0.58	0.43	³ 45	<i>Torpedo</i> sp.		68.47 (17)	
4 760	¹ 0.45	0.35	⁴ 45	<i>Trachinus</i> sp.		202.42 (12)	99.67 (3)
193	0.32	0.31	⁶ 75	<i>Trachurus</i> sp.	132.87 (8)	190.44 (108)	
35	0.14	0.04	³ 50	<i>Trigla</i> sp.	77.50 (12)	39.88 (7)	
243	0.47	0.29	⁴ 60	<i>Upeneus moluccensis</i>		166.67 (3)	
10 468	¹ 0.34	0.51	⁴ 25	<i>Venus</i> sp.	83.22 (123)	33.55 (38)	
113	¹ 1.51	0.80	³ 80	<i>Xiphias gladius</i>			106.52 (699)
4 402	¹ 0.21	0.46	³ 60	<i>Zeus faber</i>		119.83 (6)	
189	0.16	0.10	³ 55	Gobiids	77.52 (80)		48.60 (10)
4 015	0.41	0.69	³ 60	Mullids	94.05 (39)	95.68 (109)	68.37 (49)

Table 4. Group risk of exceeding the ADI at the 5% risk level

Group identification	Number of panelists on file (fishermen's relatives in brackets)	Number of persons at 5% risk level (in brackets those whose average intake exceeded their ADI)		Percentage of persons at 5% risk level	
		R factors	S factors	R factors	S factors
RAVENNA					
All panelists ¹	184 (130)	33 (7)	34 (6)	17.93	18.48
All panelists ²	179 (126)	33 (7)	34 (6)	18.44	18.99
Women in childbearing age ² (16-45 years)	41 (28)	5 (1)	6 (1)	12.20	14.63
Children ² (1-10 years)	14 (8)	6 (3)	5 (3)	42.86	35.71
Youths ² (11-18 years)	29 (22)	9 (1)	5 (0)	31.03	17.24
Aged persons ² (≥60 yrs)	27 (16)	4 (0)	7 (0)	14.81	25.93
FIUMICINO					
All panelists ¹	211 (111)	97 (60)	96 (61)	45.97	45.50
All panelists ²	198 (104)	97 (60)	96 (61)	48.99	48.48
Women in childbearing age ² (16-45 years)	44 (24)	21 (13)	23 (12)	47.63	52.27
Children ² (1-10 years)	32 (18)	20 (15)	20 (14)	62.50	62.50
Youths ² (11-18 years)	41 (27)	20 (11)	16 (11)	48.78	39.02
Aged persons ² (≥60 yrs)	14 (4)	4 (3)	3 (2)	28.57	21.43
BAGNARA					
All panelists ¹	243 (71)	205 (172)	215 (179)	84.77	88.48
All panelists ²	237 (66)	205 (172)	215 (179)	86.92	90.72
Women in childbearing age ² (16-45 years)	53 (15)	42 (32)	44 (38)	79.25	83.02
Children ² (1-10 years)	40 (1)	39 (37)	38 (35)	97.50	95.00
Youths ² (11-18 years)	38 (11)	33 (25)	33 (22)	86.84	86.84
Aged persons ² (≥60 yrs)	22 (8)	19 (15)	22 (18)	86.36	100.00

¹ Non-eaters incl.² Non-eaters excl.

The second module, pertaining to consumption data, has been split by us into several components. It calculates the daily intake of mercury per person. The contaminant level in seafood being considered a lognormal variable, the daily intake is the average of several such independent lognormal variables and itself believed to have a normal random distribution (NOAA/NMFS, 1980). The allowed daily intake (ADI), set at 30 μg per 70 kg standard person (total mercury, out of which 95% or approximately 28.6 μg are methylmercury), is computed once mean and variance have been calculated. If the 95th percentile of the daily intake distribution is below the ADI, one is 95% confident that the intake is below the allowed level. In the opposite case, it is concluded that there is a $>5\%$ risk of exceeding the level allowed. The model predicts such risk at various confidence levels. The single components of the module comprise information on the family members participating in the enquiry, such as personal ID, sex, age, weight and presence at the meals, as well as quantity (expressed as edible weight) and quality of seafood consumed by the family. Subsequently, the family meal is broken down to the subjects present with a key based on the energy requirements as established by the Commissione *ad hoc* della Società Italiana di Nutrizione Umana (1977) (Table 1), later referred to as "R factors".

This however, presumably results in an under-estimation of the consumption of aged persons whose digestive efficiency tends to decline, triggering an increase of ingestion to extract the same amount of energy. Therefore, in a subsequent run, the family meal was broken down according to average serving size for seafood assessed in the US that better reflects this phenomenon (quoted in NOAA/NMFS, 1978), subsequently referred to as "S factors" (Table 2).

Quantity, quality and frequency of consumption may then be altered to simulate changes in dietary habits in response to management decisions, accessibility of the resource and to estimate the role of any single species or set of species in mercury intake. Likewise, discrete groups of panelists can be defined and their risk assessed separately, i.e. women in childbearing age. Table 3 lists seafood consumed in the three selected coastal sites, their relative importance during the enquiry, their mercury content as estimated utilizing all records on file, and the percentage of edible parts. Its single elements, except the figures on edible parts, are produced by the simulation model and were so rearranged only to save space. The mercury levels given represent weighted averages of all records on file, irrespective of whether the individual value complied with the 0.7 ppm standard set in Italy or not, as it is only enforced for imported fish and fish products, and a sizeable portion of the fish was not acquired through market structures anyway, thus out of the range of any potential food inspection.

Results and discussion

Most results are presented by single site, instead of pooling them because no attempt was made to gather data representative of the Italian population or sections of it and because different conditions existed in the three coastal villages in question. In all three sites, average fish consumption appeared much superior to the overall Italian average when extrapolating from the enquiry period. For all panelists (eaters and non-eaters) the yearly consumption would then be estimated at 20.0 kg in Ravenna, 24.2 kg in Fiumicino and 27.1 kg in Bagnara, all expressed as effectively-edible fraction.

Table 4 shows risk levels for separate runs with S and R factors. Apart from listing how many panelists out of the total were at risk in any one place, subsequent runs included only fish eaters, women in childbearing age (16 to 45 years old), children between 1 and 10 year of age, youths 11 to 18 years old and aged person (≥ 60 years of age). Figures given in this table refer to the 95% confidence limit or, in other words, to those panelists taking an at least 5% risk of exceeding their ADI. Out of the total of 638 panelists, 147 had a daily fish consumption inferior to the Italian average (44 in Ravenna, 76 in Fiumicino and 27 in Bagnara). These include 24 who reported not to have eaten any fish in the period in question or as always being absent from the family meal and thus appear as non-eaters (5, 13 and 6, respectively). Forty-nine panelists have a much inferior average fish consumption because they reported being absent from meals in more than half the cases. From the age and sex structure, it seems that about 23 out of these may have eaten also outside the home without reporting; their mercury intake, therefore, is likely to have been under-estimated.

While the breakdown of the family meal to individuals by R factors produces a rapid increase in intake in children and youths but a decline in aged persons as compared to adult males between 20 and 49 years of age, S factors "feed" children an inferior portion but increase those of adult women and of aged persons of both sexes. This is generally more felt in intakes close to the ADI, while the group risk would barely be modified anyway from intakes well above or below the ADI.

Comparing the three sites, the differences are rather striking: while in Ravenna the average intake of panelists rarely exceeded their ADI, in Bagnara Calabria this was so at least in one member out of each family. This was due to a generally inferior consumption in Ravenna, as well as to the species composition, favouring species low in mercury. In Bagnara, instead, not only was the quantity of fish consumed higher than in any other place, but a considerable fraction was made up of species of elevated mercury level, such as swordfish. Consumption was also more even in Bagnara, with only about 10% of the panelists below the Italian average. In Fiumicino, on the other hand, though taking an overall intermediate position, whether in terms of fish consumption or mercury intake, panelists in fact form two quite distinct groups. This is reflected, for instance, in about 30% of them having a below-average fish consumption and a relatively high number of non-eaters, with the remainders consequently approaching the high Bagnara consumption levels. The two groups correspond quite clearly to non-fishermen's and to fishermen's families, respectively. The former group behaves similarly to Ravenna panelists, while the latter is closer to Bagnara's. Both being groups of roughly equal size, about 50% of panelists at Fiumicino (i.e. fishermen and their families) were consequently estimated to exceed their ADI.

While intake and, consequently, group risks seem very high as compared to what might be expected in the "average" population (NOAA/NMFS, 1978), in Fiumicino the enquiry hit the period of maximum fish landings and in Bagnara the peak of the swordfish season, which will tend to enhance fish consumption. Comparison of species composition of the diet with the monthly market statistics in the regions to which the coastal sites we selected pertain (Emilia-Romagna, Lazio and Calabria) (Istituto Centrale di Statistica, 1981) shows the best agreement in terms of abundance on the market and the frequency of consumption during the enquiry for Ravenna and a bit less for Fiumicino. The consumption pattern in Bagnara seems more independent from offer on the markets in Calabria. In all three places, though anchovy was much more abundantly marketed, sardines were favoured as food. Thus, consumption as assessed in Ravenna may be considered slightly underestimated, while in Fiumicino and Bagnara it may have been overestimated.

In Bagnara, in particular, swordfish is abundant three months of the year and during this period it was consumed by the panelists at an average of about one meal per week. At a serving size of 106.5 g, this alone would make up for the allowable intake of a 54 kg person for one week. At the same time, small tuna contribute considerably to the diet in this place. In fact, both these species figures among the "top ten" food species, eaten by 243 and 106 panelists respectively. Sardines (*Sardina*) and cuttlefish (*Sepia*) figured on places 1 and 2 of the hit list, included in the diet of 390 and 319 panelists respectively. Squid (*Loligo*) and European hake (*Merluccius*) with 228 and 223 panelists, follow. The other four species were octopus (221 panelists), whiting (*Merlangius*, 214), deepwater pink shrimp (*Parapenaeus*, 187) and mantis shrimp (*Squilla*, 179). Other species, also quantitatively important, though eaten by a slightly inferior number of panelists, included blue mussel (*Mytilus*, 178), picarel (*Maena*, 178), sprat and small unidentified clupeids (*Sprattus*, 131) pilchard (*Engraulis*, 127) and horse mackerel (*Trachurus*, 62).

With these considerations in mind, mercury intake levels still remain high, particularly in the "easy access" group of fishermen and their families. It must not be expected, though, that subjects exceeding their ADI necessarily display clinical symptoms such as paraesthesia, since the ADI as fixed for humans involves a tenfold safety margin. This implies that only with a long-term intake 10 times higher than the tolerable one, prevalence of early symptoms was to be expected in 5% of the population, the so-called most sensitive group (WHO, 1976). However, the maximum average intake (R factors) during our enquiry was 8.6 times the ADI in a three year old child. Several children exceeded their ADI five to six times while adults seldom had intakes up to four times their ADI. Thus children appear particularly vulnerable. The second group of concern are unborn babies, in view of the high number of women of childbearing age that actually exceeded their ADI in connexion with the findings of MARSH *et al.* (1977) revealing a correlation between peak concentrations (intake) of methylmercury during pregnancy and the neurological and developmental effects observed in exposed infants in Iraq (see also PIOTROWSKI and INSKIP, 1981). We have no evidence of pregnant panelists but the mercury intake levels of women in the age group 16 to 45 suggest potential hazards.

Unfortunately, at this stage, we did not have the means for parallel medical observations to verify our estimates and compare them with blood and hair analysis or through medical examination. RIOLFATII (1977), in analysing blood of 52 adults in Reggio Calabria, 20 of which reported having eaten fish three to more than four times a week, yielded two subjects within the range associated with the earliest effects and six very close to it, although no such effects were found.

PACCAGNELLA *et al.* (1974), in their study in Carloforte, a fishing village on a small island south of Sardinia, where fish consumption averages 3.8 meals per week, report mercury levels in hair and blood mostly inferior to the critical but above the recommended tolerable ones in 65% and 87% of the cases respectively. They found a significant positive correlation between hair or blood mercury levels and age of both sexes except for blood levels in females. No blood samples were taken from children, but mercury-in-hair levels averaged lower than that of adults. Fourteen out of 188 medically-examined individuals, or 7.4%, displayed neurological defects as compared to 6.6% in the rural population of two villages near Padua, northern Italy; one was a 10-year old child.

In 1974, a "hot-spot" area near Livorno, in northern Italy, was investigated by BACCI *et al.* (1976). Mercury levels in fish captured by the artisanal fisheries near the discharge of a chlor-alkali plant averaged 2.1 mg/kg. Fish consumption peaked in summer with 12 of the 20 adult panelists eating fish more than four times per week. In the July sample, mercury levels in the erythrocyte fraction of the blood of 17 individuals exceeded the recommended level and one subject was in the critical range, but no neurological effects were detected. Reduced fish consumption during the winter, on the other hand, was subsequently reflected in lower blood levels. Even though no intake was estimated nor the weight of the panelists given so that direct comparison cannot be made, it seems that mercury intake in the individuals most frequently eating fish will have been roughly double the highest one in Bagnara.

Conclusions and future research needs

From the above it appears that there is a sizeable number of persons in the three selected Italian fishing villages that exceed their allowable daily intake of mercury, particularly in Bagnara Calabria where, due to the structure of the fisheries and the catch composition, more species with high mercury levels are consumed and quantitatively more fish is eaten than in other places. While it appears that many adult panelists "consume" their safety margin by exceeding their ADI up to about four times, this fact in itself must not stir up overreactions. There are two groups, however, that require further attention: children, seeming to be particularly vulnerable since their mercury intake in relation to their body weight is frequently superior to that of adults, and women in childbearing age, often exceeding their ADI, because of the risks for prenatal life associated with peak mercury intakes, especially in the brain formation period.

For the coastal population in general it should of course be borne in mind that, despite our identifying exposed subjects, the outcome of this pilot study is barely quantitative. The tentative results need to be evaluated in the light of a general disclaimer determined by the limited resources at our disposal.

1. Only gross weight of fish was reported, obliging us to apply conversion factors to estimate the edible part. But the effectively consumed one will also be influenced by preference for, value and availability of the species.
2. A related problem is the reporting by family rather than by individual, introducing additional imprecision, particularly for small number of panelists.
3. As mentioned before, almost exclusive family reporting had the other disadvantage of leaving unaccounted for any fish meals family members might have taken outside the home, consequently under-estimating their mercury intake. On the other hand, family members may have been reported as absent from the meal with the total quantity being distributed among the rest of the family by the model while, in fact, they might have been served their portion upon return. In such a case, the absent subject would have an intake inferior to the real one, while that of the other family members would be over-estimated.
4. Furthermore it would be desirable to check on how closely the mercury-in-fish data set portrays the true intake
 - a. with respect to species that were substituted for by mixes of similar species, and
 - b. to what extent the panelists were "fed" fish from other parts of the Mediterranean.
5. Just another aspect not accounted for satisfactorily in our pilot study is the seasonality in fish availability, and thus consumption, in a situation where fresh fish is consumed, and canned or otherwise preserved fish products play a negligible role.

With this evidence of a potential mercury problem, future research should concentrate on a representative study of the whole coastal population to estimate the scale of the problem which, in turn, will have a bearing on the measures adopted to tackle it. This could suitably be done by institutions specialized in surveys such as the National Statistical Survey or Nutritional Authorities, perhaps with the assistance of public health institutions. One, although expensive, way to overcome some of the above-mentioned shortfalls in relation to the reliability of individual data would be a duplicate diet study such as the one carried out in fishing communities around the northeastern Irish Sea (HAXTON *et al.*, 1979). This would not only help to determine the exact individual consumption, thus avoiding points 1 and 2 and, to some extent, 3, but would also verify the representativeness of the mercury file (point 4).

At the same time, insisting on a more rigorous "outside-of the home" reporting would definitely improve individual data of the respective panelists and thus account for point 3.

A future study could also look into the question of the protective role of selenium against mercury poisoning, an aspect which we had to disregard altogether because of an insufficient selenium data base.

It might also be desirable to take blood and hair samples, particularly of those panelists known to exceed their personal ADI.

Eventually, special attention should be dedicated to prenatal life and exposure of children.

Such studies will remain in any case difficult and expensive to conduct, however, one has to bear in mind that any manifest health effect is irreversible. For this reason, we believe that research directed to identifying physiological indicators of pre-clinically relevant exposure should be encouraged. Once determined, and provided an easy and relatively cheap routine methodology can be developed, they could take the place of previous types of investigations.

Acknowledgements

The authors wish to thank the FAO(GFCM)/UNEP Co-ordinated Pilot Project, Baseline Studies and Monitoring of Heavy Metals for granting permission to utilize a great number of analytical data on mercury in fish. Likewise, we acknowledge with thanks the access to data on seafood marketed in Italy that was kindly granted by the Italian Ministry of Health, Rome and the assistance of D. LEVI of the Fishery Technology Laboratory in Ancona for associating vernacular fish denominations with scientific names.

References

- AKIELASZEK, J.J. and HAINES, T.A., (1981). - Mercury in the muscle tissue of fish from three northern Maine lakes. Bull. Environ. Contam. Toxicol., 27 : 201 - 8
- ARIMA, S. and UMEMOTO, S., (1976). - Mercury in aquatic organisms. 2. Mercury distribution in muscles of tunas and swordfish. Bull. Jap. Soc. Sci. Fish., 42 (8) : 931 - 937 (in Japanese, summary in English)
- ASTIER-DUMAS, M. and CUMONT, G., (1975). - Consommation hebdomadaire de poisson et teneur du sang et des cheveux en mercure en France. Ann. Hyg. Lang. Fr. (Méd. Nutr.), 11 (2) : 135 - 139
- BACCI, E. and RENZONI, A., (1973). - Indagine preliminare sul contenuto in mercurio totale in alcuni pesci dei fiumi del Monte Amiata. Rass. Med. Speriment., 20 (1) : 60 - 67
- BACCI, E. et al., (1976). - Etude sur une population humaine exposée au méthylmercure par la consommation de poisson. Rev. Int. Océanogr. Méd., 41/42 : 127 - 141
- BECKETT, J.S. and FREEMAN, H.C., (1974). - Mercury in swordfish and other pelagic species from the Western Atlantic Ocean. NOAA Tech. Rep. (Spec. Sci. Rep. - Fish. Ser.), NMFS, (675) : 154 p
- BERNHARD, M., (1978). - Heavy metals and chlorinated hydrocarbons in the Mediterranean. Ocean Managem., 3 : 253 - 313
- BRINCK, J.W. and VAN WAMBEKE, L., (1974). - World resources of mercury. In: Proceedings of the First International Congress on Mercury, Barcelona, 6 - 10 May 1974. Madrid, Fabrica Nacional de Moneda y Timbre, vol. 1, pp. 49 - 53
- CARNOVALE, E. and MIUCCIO, F.C., (1979). - Tabella di composizione degli alimenti. Roma, Istituto Nazionale della Nutrizione, 48 p.
- CAVIGLIA, A. and CUGURRA, F., (1978). - Further studies on the mercury contents of some species of marine fish and molluscs. Bull. Environ. Contam. Toxicol., 19 : 528 - 537
- CLARKSON, T.W., AMIN-ZAKI, L. and AL-TIKRITI, S.K., (1976). - An outbreak of methylmercury poisoning due to consumption of contaminated grain. Fed. Proc. Fed. Am. Soc. Exp. Biol., 35 (12) : 2395 - 2399
- CLEMENTE, G.F., CIGNA-ROSSI, L. and SANTARONI, G.P., (1977). - Trace element intake and excretion in the Italian population. J. Radioanal. Chem., 37 : 549 - 558
- Commissione ad hoc della Società Italiana di Nutrizione Umana (Ad Hoc Committee of the Italian Nutrition Society), Livelli di assunzione giornalieri raccomandati di nutrienti per la popolazione italiana. Roma, Commissione ad hoc della Società Italiana di Nutrizione Umana
- CUMONT, G. et al., (1975). - Bilan de la contamination des poissons de mer par le mercure à l'occasion d'un contrôle portant sur 3 années. Ann. Hyg. Lang. Fr. (Méd. Nutr.), 11 (1) : 17 - 25
- DENTON, G.R.W. and BRECK, W.G., (1981). - Mercury in tropical marine organisms from North Queensland. Mar. Pollut. Bull., 12 (4) : 116 - 121
- DOI, R. and UI, J., (1975). - The distribution of mercury in fish and its form of occurrence. In: Heavy metals in the aquatic environment, edited by P.A. Krenkel. Oxford, Pergamon Press, pp. 197 - 221
- ESTABLIER, R., (1973). - Nueva aportación sobre el contenido en mercurio de peces, moluscos y crustáceos del Golfo de Cadiz y caladeros de la costa oeste africana. Invest. Pesq., Barc., 37 (11) : 107 - 114
- FAO, (1980). - MED POL II : Baseline studies and monitoring of metals, particularly mercury and cadmium, in marine organisms. In: UNEP/FAO/WHO/WMO/IAEA/IOC, Co-ordinated Mediterranean monitoring and research programme (MED POL) Part I: Summary scientific report, February 1975 - December 1980. Geneva, UNEP/WG.46/3 Part I, pp. 5 - 43
- FAO, (1981). - Yearbook of fishery statistics, 1980. Annuaire statistique des pêches. Anuario estadístico de pesca. Catches and landings. Captures et quantités débarquées. Capturas y desembarques. FAO Yearb. Fish. Stat./Annu. Stat. Pêches/Anu. Estad. Pesca, (50) : 385 p
- GATTI, G.L., MACRI, A. and SILVANO, V., (1979). - Biological and health effects of mercury. In: Trace metal exposure and health effects, edited by E. di Ferrante. Oxford, Pergamon Press, pp. 73 - 98
- GFCM/CGPM, (1980). - GFCM statistical bulletin: Nominal catches. Bulletin statistique du CGPM: captures nominales, 1968 - 1978. GFCM Stat. Bull./Bull. Stat. CGPM, (3) : 124 p
- GILLES, G. et al., (1974). - Etats de la contamination par le mercure des poissons de mer et d'eau douce In: Proceedings of the International Symposium, Problems of the contamination of man and his environment by mercury and cadmium, organized by the Commission of the European Communities. Luxembourg, 3 - 5 July 1973. Luxembourg, CEC, pp. 295 - 307
- GOCHFELD, M., (1980). - Mercury levels in some seabirds of the Humboldt Current, Peru. Environ. Pollut., (Ser. A.), 22 (3) : 197 - 220
- GRAS, G. and MONDAIN, J., (1980). - Influence de la consommation de poisson sur la teneur en mercure des cheveux et du sang chez deux groupes sociaux sénégalais différents. Rev. Int. Océanogr. Méd., 59 : 63 - 69
- HARDY, R. and SMITH, J.G.M., (1970). - Catching and processing scallops and queens. Torry Advis. Note, (46) : 10 p
- HAXTON, J. et al., (1979). - Duplicate diet study on fishing communities in the United Kingdom: Mercury exposure in a "critical group". Environ. Res., 18 : 351 - 368
- HOLDEN, A.V., (1973). - Mercury in fish and shellfish. A review. J. Food Technol., 8 : 1 - 25
- HORNE, J. and BERNIE, K., (1970). - Catching, handling and processing eels. Torry Advis. Note, (37) Rev. 11 p
- Istituto Centrale di Statistica, (1981). - Annuario statistico della zootecnia, pesca e caccia. Vol. 21. 1980. Roma, Istituto Centrale di Statistica, 123 p
- JERNELOV, A. and LANN, H., (1971). - Mercury accumulation in food chains. Oikos, 22 : 403 - 406

- MAJORI, L. et al., (1978). - Metal content in some species of fish in the northern Adriatic Sea. Comparison of two sample areas. Rev. Int. Océanogr. Méd., 49 : 41 - 43
- MAJORI, L. et al., (1978a). - Methodological research on the phenomenon of metal accumulation in Mytilus galloprovincialis and on the possibility of using biological indicators as test organisms of marine metal pollution. Rev. Int. Océanogr. Méd., 49 : 81 - 87
- MARIANI, A., SANTARONI, G.P. and CLEMENTE, G.F., (1980). - Mercury levels in food and its intake in high risk population groups. Bibl. Nutr. Dieta, 29 : 32 - 38
- MARINI, S., LANARI, I. and MORRI, L., (1978). - Contaminazione da mercurio in varie specie ittiche. Indagine sul mercato di Rimini. Ind. Aliment., 17 (5) : 384 - 386
- MARSH, D.O. et al., (1977). - Fetal methylmercury poisoning. New data on clinical and toxicological aspects. Trans. Am. Neurol. Assoc., (102) : 1 - 3
- NOAA/NMFS, (1978). - Office of Fisheries Development, Seafood Quality and Inspection Division, Report on the chance of U.S. seafood consumers exceeding the current acceptable daily intake for mercury and recommended regulatory controls. Washington, D.C., NOAA/NMFS, Seafood Quality and Inspection Division, 8 February 1978, 198 p
- NOAA/NMFS, (1980). - Office of Data Processing and Statistics, Consumer risk simulation model users' guide. Charleston, South Carolina, Southeast Fisheries Center, pag. var.
- OFFICER, C.B. and RYTHER, J.H., (1981). - Swordfish and mercury: a case history. Oceanus, 24 (1) : 23 - 41
- PACCAGNELLA, B. and PRATI, L., (1974). - Concentrazioni di mercurio totale nel sangue e nei capelli di persone non esposte professionalmente residenti in aree diverse dell'Italia. Ig. Mod., 67 (3) : 369 - 380
- PACCAGNELLA, B., PRATI, L. and BIGONI, A., (1974). - Studio epidemiologico sul mercurio nei pesci e la salute umana in un'isola italiana del Mediterraneo. In: Proceedings of the International Symposium, Problems of the contamination of man and his environment by mercury and cadmium, organized by the Commission of the European Communities, Luxembourg, 3 - 5 July 1973. Luxembourg, CEC, pp. 463 - 479
- PERNA, A., DI SILVESTRO, C. and CARACCILOLO, S., (1972). - La presenza di mercurio totale nella carne dei pesci e di altri prodotti della pesca del Mar Adriatico. Nuovo Progr. Vet., 21 : 61 - 94
- PETERSON, C.L., KLAWE, W.L. and SHARP, G.D., (1973). - Mercury in tunas: a review. Fish. Bull., NOAA/NMFS, 71 : 603 - 613
- PIOTROWSKI, J.K. and INSKIP, M.J., (1981). - Health effects of methylmercury. A technical report (1981). MARC Rep., Lond., 24 : 82 p
- RAMOS, A., DE CAMPOS, M. and OLSZYNA-MARZYS, A.E., (1979). - Mercury contamination of fish in Guatemala. Bull. Environ. Contam. Toxicol., 22 : 488 - 493
- RATSKOWSKY, D.A., DIX, T.G. and WILSON, K.C., (1975). - Mercury in fish in the Derwent Estuary, Tasmania, Australia, and its relation to the position of the fish in the food chain. Aust. J. Mar. Freshwat. Res., 26 (2) : 223 - 232
- RIOLFATTI, M., (1977). - Ulteriori indagini epidemiologiche sulle concentrazioni di mercurio nel pesce alimentare e nel sangue e capelli umani. Ig. Mod., 70 (2) : 169 - 186
- STOEPLER, M. et al., (1979). - Comparative studies on trace metal levels in marine biota. 1. Mercury in marine organisms of the western Italian coast, the Straits of Gibraltar and the North Sea. Sci. Total Environ., 13 (3) : 209 - 223
- SUKUZI, T. et al., (1980). - Selenium and mercury in foodstuff from a locality with elevated intake of methylmercury. Bull. Environ. Contam. Toxicol., 24 : 805 - 811
- Swedish Expert Group, (1971). - Methylmercury in fish. A toxicologic-epidemiologic evaluation of risks. Nord. Hyg. Tidskr./Natl. Inst. Public Health, Stockholm, Suppl. 4 : 364 p
- THIBAUD, Y., (1971). - Teneur en mercure dans quelques poissons de consommation courante. Sci. Pêche, (207) : 1 - 10
- Torry Research Station, (n.d.). - Handling and processing shrimp. Torry Advis. Note, (54) : 17 p
- TSUBAKI, T. and IRUKAYAMA, K., (Eds.), (1977). - Minamata disease. Methylmercury poisoning in Minamata and Niigata, Japan. Tokyo, Kodansha Ltd., 317 p
- WATERMAN, J.J., (n.d.). - Measures, stowage rates and yields of fishery products. Torry Advis. Note, (17) : 11 p
- WESTOO, G., (1969). - Methylmercury compounds in animal foods. In: Chemical fallout: current research on persistent pesticides, edited by M.W. Miller and G.G. Berg. Springfield, Illinois, C.C. Thomas Publishers, pp. 75 - 93
- WHEATLEY, B. et al., (1979). - Methylmercury poisoning in Canadian Indians: the elusive diagnosis. J. Can. Sci. Neurol., 6 (4) : 417 - 422
- WHO, (1976). - Environmental health criteria, 1. Mercury. WHO Environ. Health Criteria, (1) : 131 p
- Working Group on Mercury Fish, Australia, (1980). - Report on mercury in fish and fish products to Co-ordinating Committee on Metals in Fish and Fish Products, 1979. Canberra, Australian Government Publishing Service, 371 p
- YANNAI, S. and SACHS, K., (1978). - Mercury compounds in some eastern Mediterranean fishes, invertebrates and their habitats. Environ. Res., 16 : 408 - 418
- ZAITSSEV, J. et al., (1969). - Fish curing and processing. Translated from the Russian by A. de MERINDOL. Moscow, MIR Publishers, 722 p