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MEDITERRANEAN HEALTH-RELATED ENVIRONMENTAL  
QUALITY CRITERIA

Report on a Joint WHO/FAO/UNEP Meeting

Bled  
12-16 September 1988



Long-term Programme of Pollution Monitoring and Research  
in the Mediterranean Sea  
(MED POL Phase II)

1989

EUR/HFA target 20

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## TARGET 20

### Water pollution

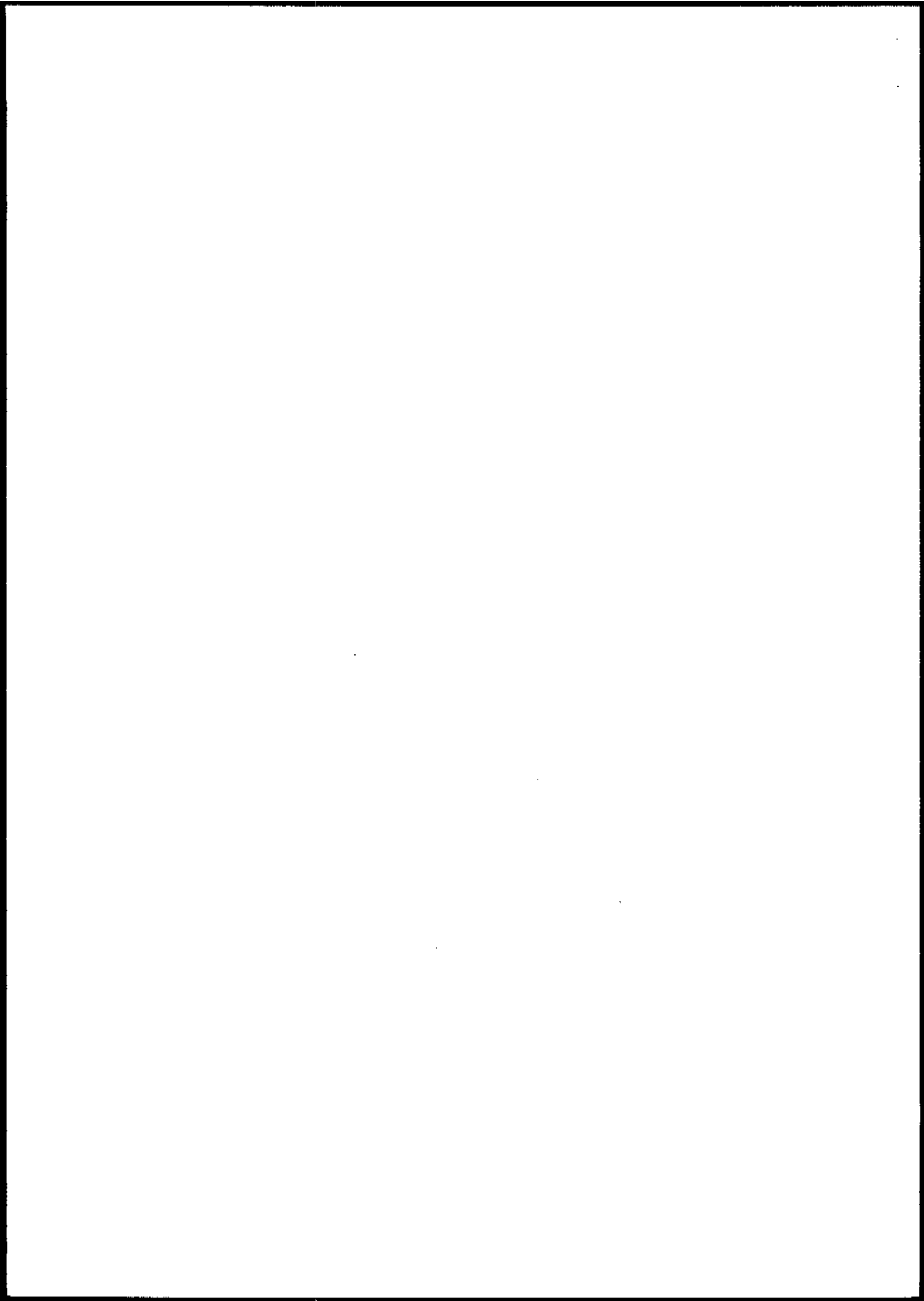
By 1990, all people of the Region should have adequate supplies of safe drinking-water, and by the year 1995 pollution of rivers, lakes and seas should no longer pose a threat to human health.

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ENVIRONMENTAL HEALTH  
ENVIRONMENTAL MONITORING  
MERCURY %AE%  
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EPIDEMIOLOGY  
MEDITERRANEAN SEA  
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## Foreword

Within the framework of the legal component of the Mediterranean Action Plan, adopted by the governments of the region in Barcelona in February 1975, and more specifically in terms of Article 8 of the Convention for the Protection of the Mediterranean Sea against Pollution, adopted and signed, also in Barcelona, in February 1976, a Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources was adopted and signed in Athens in May 1980 and entered into force in June 1983. In Article 5 of this Protocol, the Contracting Parties undertook to eliminate pollution of the protocol area from land-based sources by a number of substances (listed in Annex I to the Protocol) including mercury and cadmium and their compounds, organotin compounds and substances proved to have carcinogenic, teratogenic or mutagenic properties in or through the marine environment. Under the terms of the same Article, the Parties undertook, in particular, to elaborate and implement, jointly or individually as appropriate common emission standards and standards for use.

Similarly, under Article 6 of the Protocol, the Parties undertook to strictly limit pollution of the protocol area by a number of substances (listed in Annex II to the Protocol) including 20 metals and their compounds and, to this end, to elaborate and implement, jointly or individually as appropriate, suitable programmes and measures. Again, under Article 7 of the Protocol, the Parties undertook to progressively formulate and adopt, in cooperation with the competent international organizations, common guidelines and, as appropriate, standards and criteria dealing in particular with aspects including the quality of seawater used for specific purposes, as necessary for the protection of human health, living resources and ecosystems, as well as specific requirements concerning the quantities of the discharged substances listed in Annexes I and II to the Protocol, their concentration in effluents and methods of discharging them.

An assessment of the state of pollution of the Mediterranean Sea by mercury, mainly based on the results of monitoring activities performed by laboratories in the region between 1975 and 1981, as well as on other reliable independent data, was completed by the Food and Agriculture Organization of the United Nations (FAO), WHO and the United Nations Environment Programme (UNEP) within the framework of the Long-term Programme of Pollution Monitoring and Research in the Mediterranean Sea (MED POL Phase II) in 1983. At their fourth ordinary meeting in Genoa in September 1985, Contracting Parties agreed with the conclusion that, according to the available evidence to date, on the basis of current concentrations of mercury in seafood, as well as on that of production and consumption data, there appeared to be no risk to general populations through consumption of Mediterranean seafood, and considered therefore that, at this stage, the adoption of upper limits for mercury concentrations in seafood on a common regional basis would not be a priori justified. They also agreed, however, to take into consideration the provisional tolerable weekly intake (PTWI) (0.3 mg of mercury, of which not more than 0.2 mg should be methylmercury, for a person of 60 kg body weight) proposed by the Joint FAO/WHO Expert Committee on Food Additives, in order to establish, if national circumstances so required, standards for maximum concentrations of mercury in seafood.

During the same meeting, the Contracting Parties also agreed, however, to continue to carry out those activities within the monitoring and research components of MED POL Phase II relevant to the assessment of the mercury content of Mediterranean seafood, and the risks affecting any specific sectors of the population arising from seafood consumption, in particular:

- studies to identify population groups at risk;
- surveys of food consumption patterns among such populations;
- surveys of mercury levels in affected population groups;
- epidemiological studies to obtain the necessary information on the relationship between mercury intake and health effects;
- studies of the relationship between total mercury and the methylmercury content of seafood, and the effects of cooking on such content;
- studies on biogeochemical cycles of mercury in the Mediterranean;
- studies on the effects of selenium in decreasing mercury toxicity.

Most of the above studies had been developed by WHO in collaboration with FAO and UNEP, within the framework of the MED POL Phase II programme, and a project on the evaluation of methylmercury in Mediterranean populations and related health hazards had been finalized at a meeting in Athens in September 1982. Studies had commenced on a pilot scale in Greece, Italy and Yugoslavia in 1984, and the project had been further reviewed at meetings in Zagreb in September 1984, and in Athens in September 1986.

Similar assessments of the state of pollution of the Mediterranean Sea by cadmium, copper, zinc and lead and their compounds were developed during 1986 and 1987, but have still not been formally considered by the Contracting Parties pending revision.

Within the framework of the MED POL Phase II programme, a meeting on Mediterranean health-related environmental quality criteria was jointly convened by WHO, FAO and UNEP, in collaboration with the "Josef Stefan" Institute, Ljubljana, Yugoslavia, with the following objectives:

- to review the existing situation regarding mercury and other heavy metal marine pollutants in the Mediterranean, as well as in other regions;
- to review the results of the current phase of the project on the evaluation of methylmercury in Mediterranean populations and related health hazards, and to discuss future work, including clinical studies, as well as extension of the project to other countries in the region;
- to make a preliminary review of environmental quality and related criteria and standards eventually required for heavy metal marine pollutants in the Mediterranean, and elaborate possible study programmes;
- to make appropriate recommendations.

A number of experts from Mediterranean institutions which were either already participating in the methylmercury project, or had shown a positive interest in participating in the second phase of the project, together with a number of other Mediterranean and non-Mediterranean experts in the correlation of metal pollution of seafood with health effects, were invited to attend the meeting. In addition, the following international organizations were invited to send representatives: the Intergovernmental Oceanographic Commission (IOC), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Meteorological Organization (WMO), the International Atomic Energy Agency (IAEA) and the Commission of the European Communities (CEC).

#### 1. Opening of the meeting

The Meeting took place at the Hotel Kompas, Ribno, Bled, from 12 to 16 September 1988. It was attended by 23 temporary advisers from nine Mediterranean countries and four from non-Mediterranean countries, and one representative each from FAO, IAEA, UNEP, the International Agency for Research on Cancer (IARC), WHO headquarters and the WHO Regional Office for Europe. A list of participants is given in Annex 2.

Dr L.J. Saliba, Senior Scientist, Mediterranean Action Plan, WHO Regional Office for Europe, opened the Meeting and welcomed participants on behalf of the Regional Director, Dr J.E. Asvall. He also welcomed them on behalf of Dr Hussein Abdul-Razzaq Gezairy, Regional Director of the WHO Regional Office for the Eastern Mediterranean, which was a co-convenor of the Meeting. He outlined the importance of the Meeting within the framework of the Mediterranean Action Plan, particularly the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources, signed in 1980 and in force since 1983. This Protocol was, inter alia, concerned with the adoption of environmental quality criteria and standards, including emission standards and standards of use.

With regard to mercury, the primary conclusions reached were that, although seafood consumption appeared to present no risks to Mediterranean populations in general, certain groups, particularly heavy seafood consumers, could be at risk. The project on the evaluation of methylmercury in Mediterranean populations and related health hazards, developed in 1982 and operational in its pilot phase since 1984, had been designed to identify the range and magnitude of the problem. One of the most important items on the agenda of this Meeting was to discuss the results of the pilot phase, and to make appropriate recommendations for the future. Regarding other metals, seafood consumption was not the only and, in most cases, not even the main route of exposure. The Meeting was requested to undertake a preliminary identification of those metals that could pose a human health problem through seafood consumption, and to propose possible ways of tackling the problem in stages.

Dr Saliba expressed his thanks to the "Josef Stefan" Institute for their kind offer to host the Meeting, as well as for their excellent organizational arrangements and hospitality. In particular, he mentioned their financial contribution to the meeting budget, without which the scale of participation would have been significantly reduced.

Professor T. Kalin, Director of the "Josef Stefan" Institute, welcomed the participants. He expressed his institute's appreciation of being able to collaborate with WHO in this particular activity, and recalled other occasions in the recent past, such as the occurrence of red tides in the Adriatic and heavy metal contamination of rivers, on which similar collaboration with the United Nations had been effected. The Institute had participated in MED POL activities since the programme's inception, and had indeed been involved in the preparatory activities, dating back to 1974. Direct collaboration with WHO had commenced in 1984 with the entry of the Institute into the methylmercury project by acting as the central laboratory for hair analysis. Similar analyses had also been performed at a later date in connection with hair samples from Switzerland. Professor Kalin expressed his institute's readiness to continue participating in the methylmercury project and wished participants a fruitful and successful meeting, as well as a pleasant stay in Bled.

Mr A. Manos, Co-ordinator of the Mediterranean Action Plan, conveyed to participants the greetings of the Executive Director of UNEP, Dr Mostafa K. Tolba, and thanked the "Josef Stefan" Institute, particularly Dr P. Stegnar, for their contribution towards the organization of the Meeting. He recalled that when the pilot phase of the MED POL programme had commenced in 1975, limited information on the actual state of pollution of the Mediterranean Sea was available, and the function of the programme was to remedy this deficiency progressively, and to enable the necessary programmes and measures to be implemented, particularly those dealing with substances in Annex I and II (the "black" and "grey" lists respectively) to the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources. The assessments of the state of pollution of the Mediterranean Sea, which covered a number of substances, had shown that these substances had, through the marine environment, had a varying impact on the health of the region's population. In one particular case (organosilicon compounds), governments had decided to remove the substances in question from the pollutants listed in Annex II to the Protocol. A calendar and timetable for the preparation of the assessments, designed to cover all substances listed in both annexes, had been approved in 1985, and the assessments were expected to be complete by 1995.

Mr Manos stressed that all measures being adopted by governments had financial and/or administrative implications. Recommendations to governments were therefore only made when supported by the best possible scientific and technical advice, such as that which the Meeting could provide. The Mediterranean Action Plan as a whole was currently being refocused to concentrate on integrated coastal management. This would lead to more attention being devoted to fewer, but high-priority, marine pollutants.

Mr G.P. Gabrielides, Senior Fishery Officer (Marine Pollution), welcomed the participants on behalf of FAO and explained the role of his organization in the methylmercury project. He informed the Meeting that the Codex Committee on Food Additives at its 19th session (The Hague, March 1987) had recommended guideline levels for mercury in fish and fish products ( $0.5 \text{ mg kg}^{-1}$  for all fish, except for predatory fish such as shark, swordfish, tuna and pike for which the levels should be  $1 \text{ mg kg}^{-1}$ ), since in its view population groups with a high proportion of fish in their diets might be at risk. At the same time, the Codex Committee on Fish and Fishery Products did not think that establishing guideline levels for mercury in fish would be the most appropriate way to protect the consumer. He also informed

the Meeting that the Joint FAO/WHO Expert Committee on Food Additives at its 33rd meeting (Geneva, March 1988) had decided that there was no need to modify the existing PTWI for methylmercury.

## 2. Scope and purpose of the Meeting

Dr Saliba outlined the scope and purpose of the Meeting. The existing situation in the Mediterranean had to be reviewed, and comparisons drawn with other regions. The draft report on Phase I of the project on the evaluation of methylmercury in Mediterranean populations and related health hazards would be discussed, and the information updated by more recent results. The Meeting would have to make its recommendations regarding what form the second phase of the project should take.

Another important item was the protocol on clinical studies on the health effects of methylmercury, now submitted in its final draft version. This protocol would have to be finalized during the Meeting, with regard to both form and substance. Dr Saliba outlined suggestions which had been received so far, including (a) the separation of clinical studies on adults and children, resulting in virtually two independent protocols, and (b) the identification of core tests from the range provided in the present draft protocol.

Regarding metals other than mercury, the Meeting was expected to state which substances included in the annexes to the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources could possibly involve a hazard to human health through the consumption of contaminated seafood, either solely through this route of exposure, or in combination with other routes. For substances so identified, a tentative programme of work, even in outline, would have to be recommended in order to avoid overlap and repetition. One important point was a provisional forecast as to which substances might eventually have to be included in Mediterranean regional quality criteria and standards for seafood.

## 3. Election of officers

Professor B. Paccagnella was elected Chairman, Dr P. Stegnar Vice-Chairman, and Dr S. Nakou Rapporteur. Dr Saliba acted as Secretary to the Meeting.

## 4. Adoption of the agenda

The provisional agenda was unanimously adopted.

## 5. Organization of the Meeting

The Chairman explained the organization of the Meeting, including the working hours and other arrangements. It was agreed that the Meeting would work mainly in plenary, except for the setting up of two working groups, one to discuss the clinical studies protocol, and the other the analytical and related implications of extending the methylmercury project to other countries within the region and of commencing studies on other metals.

6. Review of the existing situation regarding marine pollution by mercury in the Mediterranean, and comparison with other regions

It was noted that considerable data on the levels of mercury in the various matrices of the Mediterranean marine environment had been accumulated, as compared with data obtained for other metals. However, even this information was still considered incomplete, and a number of results were either not comparable or were not considered to have conformed fully to accepted quality control procedures. Concentrations of total mercury in a number of edible fish species recorded by various authors had mean values of over 1.0 ppm (with recorded maximum values of 2.5 to 7.0 ppm). Mean values for some mussel and crustacean species varied from 0.1 to 1.00 ppm, with maximum values of 3.0 to 7.0 ppm). The majority of species analysed had mean values ranging from 0.1 to 0.3 ppm total mercury. The mercury content, as would be expected, varied considerably with the particular species, with age, and with the particular area. The highest concentrations had been recorded from the northwestern part of the Mediterranean basin, including the Tyrrhenian and Ligurian seas. Concentrations of total mercury recorded in sediments ranged from below 0.01 to 21.0 ppm in terms of dry weight. In the case of pelagic mammals, concentrations recorded, in terms of ppm total mercury/body weight, had reached 41 in muscle, 6 in fat and 905 in liver.

Comprehensive evaluations of the state of pollution of the Mediterranean Sea by mercury compounds were jointly prepared by FAO, WHO and UNEP in 1983 and 1987. The conclusions reached regarding effects on human health were that persons eating one or less than one seafood meal per week were very unlikely to exceed the PTWI recommended by the Joint FAO/WHO Expert Committee on Food Additives, even if the seafood consumed contained high amounts of methylmercury. However, many critical groups eating large amounts of fish and other seafood were known to exist, and estimations from seafood consumption studies carried out on persons belonging to these critical groups showed that a large proportion of such persons had a consumption exceeding the PTWI. The limited number of analyses of mercury levels in blood and hair of members of these critical groups provided sufficient evidence that the PTWI was in fact exceeded, and some of the levels found in hair were within the range where mercury poisoning could be expected.

In September 1985, Mediterranean governments agreed that the overall situation did not call for the adoption of upper limits for acceptable mercury concentrations for edible species of seafood on a joint regional basis, though any country could enforce such measures on a national basis should local circumstances so require. In actual fact, most Mediterranean countries enforce an upper limit ranging from 0.5 to 0.77 ppm of mercury in all or selected seafood species. In September 1987, Mediterranean governments adopted a resolution to ensure a maximum concentration of 50 mg total mercury per litre (expressed as total mercury) for all effluent discharges into the Mediterranean Sea, in terms of Article 5 and Annex I of the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources.

It was also agreed by Mediterranean governments that, in order to safeguard human health, the following measures would be necessary:

- the identification of heavy seafood consumers (irrespective of area);
- the monitoring of seafood consumption patterns, including type and species of seafood consumed, through dietary surveys; and the

preliminary screening of such consumers by monitoring concentrations of mercury in hair;

- similar monitoring populations in areas affected by mercury discharges, including moderate seafood consumers;
- the formulation and implementation of advisory and recommendatory measures to regulate the type and amount of seafood consumed among high-risk groups.

In order to achieve these aims, participants stressed the importance of continuing the project on the evaluation of methylmercury in Mediterranean populations and related health hazards within the framework of the MED POL Phase II programme.

The Meeting discussed the general situation regarding mercury in Mediterranean seafood and agreed that it could be summarized as follows.

(1) The implementation of the joint emission standard for mercury in waste discharges agreed to by Mediterranean governments in 1987 would alleviate the situation to some degree, particularly in areas currently subject to mercury pollution of predominantly industrial origin. However, the problem of mercury from natural sources would remain.

(2) The imposition of upper limits for the mercury concentration in fish, which several Mediterranean countries were actively implementing, could serve as a further guarantee of the safety of general populations (which, in any case, were not considered at risk). It would not, however, constitute an effective measure of protection for high-risk groups, particularly fishermen and their families since, apart from the relatively high amount of seafood consumed, this (the seafood itself) could in many instances have mercury concentrations above the acceptable limits and, not being offered for sale, would not be subject to control.

(3) Identification of all the high-risk groups could only be undertaken and confirmed through full-scale (as opposed to pilot-scale) surveys in the various countries. This would be a relatively expensive exercise, though a certain proportion of the costs could be avoided through the performance of preselection exercises.

(4) Attention would also have to be paid to the mercury content of canned and frozen seafood, originating both within and outside the Mediterranean region.

Opinion at the Meeting was divided on the question of the mercury content of fishmeal, which was used as a feed for livestock, particularly poultry. In at least one Mediterranean country, this use had resulted in an increased mercury content in both eggs and poultry flesh. It was agreed that this might be a problem in some countries, but not in others, depending on the relative amount of fishmeal in livestock diets, as well as the mercury content of the fish in question.

The mercury problem in other regions was briefly discussed, mainly as a point of comparison with the Mediterranean. The particular circumstances prevailing elsewhere, such as in Greenland and among the Canadian Indians, were not the same as in the Mediterranean, and the same solutions could not

therefore be applied directly. However, the Meeting agreed that improved liaison with non-Mediterranean groups would be of great benefit, particularly where matters of methodology and toxicology were involved.

7. Review of results of the current phase of the project on the evaluation of methylmercury in Mediterranean populations and related health hazards

The Meeting discussed the report on the current phase (1984-1988) of the project on the evaluation of methylmercury in Mediterranean populations and related health hazards as presented in document ICP/CEH 059/7 and as updated by representatives of participating institutions. The final version of the report is given in Annex 1.

After preliminary screening of more than 4000 persons through dietary surveys, a total of 1098 hair samples (659 from Greece, 241 from Italy and 198 from Yugoslavia) were analysed for total mercury and, where appropriate, for methylmercury. The criteria adopted for identification of individuals possibly at risk, as agreed at the meeting on the health effects of methylmercury in the Mediterranean area (Athens, 15-19 September 1986) were total hair mercury levels of 25 ppm for adults and 6 ppm in maternal hair for newborns.

The results of the study confirmed that there is a positive correlation between seafood consumption and levels of total mercury and methylmercury in hair. On the basis of the criteria detailed above, no at-risk individuals were identified in the Yugoslav survey. In the Greek population evaluated, there was no evidence of risk to the large majority, but the criteria were exceeded in some residents of isolated fishing communities, including fishermen and women of child-bearing age, consuming very large amounts of seafood. The major part of the Italian population surveyed was also considered as free from risk, the at-risk groups being heavy seafood consumers such as fishermen spending considerable amounts of time at sea, and babies who had high-level intrauterine exposure from maternal seafood consumption.

The Meeting reviewed the draft protocol on clinical epidemiological studies on the health effects of methylmercury, which had been revised to reflect the amendments suggested by the 1986 Athens meeting referred to above. In discussing such studies, the Meeting took into account the fact that the early clinical effects of methylmercury on the central nervous system were non-specific and that, at the levels of exposure indicated by hair mercury levels found in the Mediterranean population groups studied, neuropsychological changes, if any, were likely to be small. The number of individuals detected to date with hair mercury levels exceeding the criteria adopted in 1986 was very small, and it therefore appeared that, in the Mediterranean region, clinical epidemiological studies would need to be collaborative to ensure adequate size. It was recognized by the Meeting that the population size required for any test would depend both on the type of test used and on the background level of abnormalities in the populations studied. It was stressed that the pooling of data would increase the problem of confounding variables. Regarding adults, as described in the draft protocol, WHO had already developed a battery of neurological and psychological tests (NCTB), and this could be used for the study.

Tests for studies on prenatally exposed children had to be sensitive, simple to apply and able to discriminate for subtle changes. The relevant parts of the draft protocol were considered to constitute a useful reference

document for developing a definitive protocol, and the tests selected by any country would depend on the persons administering the test, as well as on the types of test which had already been standardized and used for investigating other child development problems in that country. It was noted that in neuropsychological and behavioural testing of children, many factors, other than mercury exposure, influenced a child's performance, and that these factors would have to be taken into account. The older the child at testing, the greater the number of confounding variables.

A variety of tests, each covering a specific aspect of child development, were considered appropriate. The Meeting noted that a battery of neuropsychological tests and behavioural tools was being assembled by WHO for use in other studies on child development, and this could be of use to the methylmercury study.

The Meeting also briefly reviewed the results of other studies carried out in various areas in Italy between 1972 and 1988 involving hair analyses of both exposed and control populations and, in many instances, correlation with levels of mercury in seafood. Only a very small percentage of the populations sampled in these studies could be considered to be at risk.

#### 8. Future work on mercury in the Mediterranean

The Meeting agreed that the next phase of the project should concentrate on identifying groups at risk on a broader Mediterranean regional basis, and that attention should be focused on (a) women giving birth and (b) adult fishermen, from coastal areas where mercury levels in seafood were high or where seafood consumption was above four meals per week. The main concentration should be on exposure of the fetus, considering its much greater sensitivity to methylmercury. Activities were expected to be as follows:

- identification by Mediterranean countries of coastal communities with a relatively high seafood consumption (four or more seafood meals per week);
- review of already existing data on mercury levels in the main seafood species consumed in such areas, complementing these by measurements wherever necessary;
- analysis of hair mercury levels of individuals considered at risk;
- clinical epidemiological studies on adults, and eventually on children, to determine effects.

It was noted that a number of Mediterranean countries had already established that there were no such at-risk communities along their coastline and that, in a number of others, participation in the second phase of the project would depend, to varying extents, on the existing national health priorities and/or on the current capacities in terms of equipment and trained manpower. It was also understood by the Meeting that this orientation of the project would not preclude giving consideration to any relevant research projects which could provide further input into the overall picture, both for acceptance into the MED POL programme and for the provision of financial and other assistance therefrom.

A number of participants outlined the plans of their institutions and/or national authorities for future research and biological monitoring of populations, both as proposed contributions within the framework of the MED POL programme, or independently. In particular, a programme for hair mercury screening of coastal populations, involving a number of laboratories throughout the country, was expected to be under way shortly in Italy.

The Meeting noted that the PTWI of 0.3 mg total mercury (of which no more than 0.2 mg should be present as methylmercury) established by the FAO/WHO Joint Expert Committee on Food Additives in 1972 had remained unchanged, and that the most important gap in knowledge at global level was at the lower end of the dose-response relationship for prenatal exposures. Following considerable discussion, it was agreed that for the purposes of initial clinical follow-up of indicated individuals during the next phase of the project, the criteria should be hair total mercury levels of 50 ppm and above in adults, and 10 ppm and above in women giving birth. While the main problem was methylmercury, total mercury was recognized as the best primary indicator. Final evaluation would depend on methylmercury levels. Clinical tests could later be extended to children of women having whatever hair mercury level below 10 ppm was considered useful and/or justifiable.

On the basis of results obtained, the only group qualifying for such clinical follow-up would be adult male fishermen from Italy. In the case of females, it was felt that not enough material was available at the present stage to justify initiating clinical studies on children of exposed mothers.

The Meeting also noted that several countries outside the Mediterranean were involved in studies on mercury exposure and health effects. The MED POL programme would benefit from direct access to the relevant data, and the establishment of an information-exchange mechanism at a global level would be extremely useful.

9. Review of the existing situation regarding metals other than mercury included in the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources

The Meeting briefly reviewed the existing situation in the Mediterranean regarding marine pollution by metals other than mercury, and possible health effects through consumption of contaminated seafood.

9.1 Cadmium

Humans are exposed to cadmium from ambient air, drinking water, tobacco and food. Unlike the case of mercury, where seafood constitutes the main source of human intake except in cases of occupational exposure, the contribution of seafood to people's overall cadmium intake may be regarded as small. Nevertheless, substantially large amounts of cadmium have been recorded in some species of Mediterranean seafood; such levels could, in the case of heavy seafood consumers, result in adverse health effects on their own or, in the case of more moderate consumers, provide an intake which, when combined with that from other sources, might tip the scale between relative safety and risk.

No systematic survey of cadmium sources has so far been carried out in the Mediterranean. Data on both natural and anthropogenic sources came to light only when higher than average concentrations of cadmium were observed in marine organisms and sediments.

An assessment of the state of pollution of the Mediterranean Sea by cadmium and cadmium compounds was prepared by FAO, WHO and UNEP in 1987. In this assessment, it was pointed out that although the PTWI of 400-500 mg cadmium for a man, proposed in 1972, had been found generally acceptable, some experts considered the figure too high, and it had been suggested that a more conservative intake level would be around 300 mg for a person of 70 kg body weight. Correlation of the cadmium levels recorded with the PTWI figures drew the conclusion that persons who are low seafood consumers (1-2 meals per week) appeared to run no risk of exceeding the PTWI, even considering that the main sources of cadmium intake were not of marine origin, provided that these persons did not eat the high-contaminated species (mainly mussels). The situation was not the same for high seafood consumers, and persons habitually consuming large amounts of mussels from cadmium-contaminated areas could easily exceed the PTWI, especially in view of the other important sources of intake.

The main conclusion reached in the FAO/WHO/UNEP assessment on cadmium in the Mediterranean with regard to health effects on people was that, since the average cadmium intake from food of mainly terrestrial origin and from tobacco was known to be only slightly lower than the tolerable intake, every effort should be made to reduce the overall cadmium intake, including that from seafood. The need for national surveys aimed at identifying individuals ingesting high amounts of cadmium, both from seafood and from other sources, had also been stressed.

For this reason, it had been recommended that the overall criteria for the protection of human health with regard to cadmium intake should be based on the PTWI, and should take into account all sources of cadmium. Ideally, this problem should be tackled globally, with seafood as one of the components. In so far as seafood alone was concerned, however, the following measures had been recommended by FAO/WHO/UNEP as necessary, in addition to the imposition of emission standards and related measures aimed at reducing the overall amount of cadmium in the Mediterranean marine environment:

- monitoring seafood species to determine their cadmium content;
- identification of areas where the current concentration of cadmium in edible seafood species would pose a health problem, taking into account cadmium intake from other sources;
- the imposition of legal limits on the cadmium content of seafood in such areas, or any other restrictions considered appropriate under prevailing conditions, should the local situation so demand;
- formulation and implementation of advisory and recommendatory measures to regulate the type and amount of seafood consumed by high-risk groups, if such groups are considered not to be sufficiently protected by local measures of a more general nature.

The Meeting noted that the recommended measures, consisting of the adoption of an upper limit of 0.2 mg cadmium (expressed as a monthly average) per litre for all effluent discharges into the Mediterranean Sea, had still to be formally submitted to Mediterranean governments for consideration and adoption.

During the general discussion, high cadmium levels in certain species of bivalves (oysters, clams, etc.) in the Mediterranean, as well as along the coasts of the Atlantic, were reported. Recent studies on oysters and on people with high oyster consumption in non-Mediterranean areas had indicated that cadmium in bivalves is not metabolized by the human body in the same way as cadmium in staple foods. Cadmium in bivalves could therefore be much less toxic than cadmium in other foodstuffs, and the guideline values for daily intake by humans, or for maximum acceptable levels in oysters, would need to be carefully assessed.

### 9.2 Organotin compounds

Although there was considerable international data on organotin compounds, no information was currently available on the theoretical or actual load of these compounds being discharged into the Mediterranean Sea. It appeared likely that the greatest pollution potential for the Mediterranean arose from biocidal use of triorganotin compounds in antifouling products, localized around the areas where such products were commonly used.

An assessment of organotin compounds as marine pollutants was prepared by UNEP, FAO, WHO and IAEA in 1988. One of the conclusions reached had been that, although no specific information was available on triorganotin levels in the Mediterranean area with the exception of some methyltin measurements in coastal environments in Turkey, concentrations of tributyltin (TBT) considerably in excess of the 1-20 ng/l range constituting appropriate water quality standards could be expected to occur in hot-spots. Chemical and biological monitoring and research projects were currently in progress to validate this assumption.

Recently an attempt had been made to estimate the acceptable daily intake for tributyltin oxide (TBTO) for humans, and a committee of the Japanese Ministry of Health and Welfare had proposed an ADI for humans of 1.6 mg TBTO per kg of body weight, meaning that a person with a body weight of 60 kg could ingest 96 mg of TBT per day. On the basis of consuming 100 g (wet weight) of seafood per day, this ADI would correspond to an "acceptable" contamination level of TBT in fish and shellfish of about 1 mg TBT per kg of wet seafood. It was considered that this level could be exceeded, either in highly polluted waters or in aquaculture farms using cages with TBT-treated netting.

The Meeting noted that a pilot project on levels of organotin compounds in selected Mediterranean areas was currently under way within the framework of the MED POL Phase II programme, and that the situation would be reviewed in the light of results from this study.

### 9.3 Lead

In a survey of pollutants from land-based sources in the Mediterranean, performed jointly by the United Nations Economic Commission for Europe (ECE), FAO, UNESCO, WHO, the United Nations Industrial Development Organization (UNIDO), IAEA and UNEP in 1977, the total annual input of lead into the

Mediterranean Sea had been calculated at 4300 to 5400 tons, including 2700-3800 tons carried by rivers. The atmospheric input, which could be important, particularly in this case, had not been considered by the project. Very little data were available so far on levels of lead in marine organisms in the Mediterranean.

A PTWI of 3.0 mg of lead for adults had been recommended by the Joint FAO/WHO Expert Committee on Food Additives in 1972. This would be equivalent to approximately 430 mg per day for a person of normal body weight. Even considering the limited data available on levels of lead in Mediterranean seafood, it would not appear that seafood consumption could pose a health hazard on its own. However, especially in the case of heavy seafood consumers, this would have to be considered both in absolute terms (i.e. contamination levels and consumption) and in association with exposure to lead from other non-marine sources, the latter representing the main overall source.

The Meeting noted that a preliminary assessment of the state of pollution of the Mediterranean Sea by lead (together with cadmium, copper and zinc) had been prepared by FAO and UNEP in 1986. In the case of lead, no specific recommendations had been made, pending the acquisition of more data.

#### 9.4 Arsenic

There was no information available on the amounts of arsenic entering the Mediterranean Sea. Levels ranging from 5.0 to 83.0 ppm in bivalves (wet weight) had been reported from various Mediterranean areas.

A hazard evaluation for arsenic prepared by the Group of Experts for the Scientific Assessment of Marine Pollution (GESAMP) in connection with a review of potentially harmful substances (1985) stated that no data were currently available concerning the toxicity of the organic arsenic compounds present in seafoods for humans. However, it appeared obvious that the toxicity, at least of the major compound, arsenobetaine, was much lower than for inorganic arsenic, otherwise acute effects ought to have been observed. The working group also commented that, considering the high concentrations in food products eaten over a lifetime by a large number of people and the relatively long retention times in certain tissues, the accumulation and possible effects following long-term exposure needed to be investigated. It was also important to identify the other organic arsenic compounds, water-soluble as well as fat-soluble, which, although present at low concentrations in seafood, could be of greater toxicological significance than arsenobetaine. There was also a need for data on the placental transfer and effects of the various organic arsenic compounds present in seafood. The group also recognized the teratogenic effects of inorganic arsenic compounds in experimental animals.

In the WHO Environmental Health Criteria document for arsenic (1981), from which the recommendations of the 1985 GESAMP meeting were largely drawn, it was also stated that there was (at the time) no conclusive evidence that any of the organoarsenic compounds tested for carcinogenicity in laboratory animals were carcinogenic, and that epidemiological studies were greatly needed on populations exposed to organic arsenic, especially in view of the discrepancy between animal and human data with regard to the carcinogenicity of inorganic arsenic compounds. Also, data had not been reported concerning the possible carcinogenic effects of "seafood arsenic", which is mainly organic, although the form of arsenic present is still largely unknown.

Practical analytical data also indicated that a small percentage of the arsenic present in fish and possibly other seafood could be in inorganic form. If such was the case, seafood consumption would contribute, perhaps considerably, to a person's daily intake of inorganic arsenic.

An assessment of the state of pollution of the Mediterranean Sea by arsenic was scheduled for preparation by the end of 1990, and it was expected that monitoring on a pilot scale to provide analytical data on arsenic levels would commence in 1989.

The Meeting also noted that considerable attention had been paid to arsenic during the WHO/FAO/UNEP meeting on carcinogenic and mutagenic marine pollutions in the Mediterranean, held in Athens from 23 to 25 June 1988, and that this substance would be included in the programme of action to follow up that meeting.

#### 9.5 Selenium

There was no information available regarding the amounts of selenium reaching the Mediterranean. The only cases where selenium levels had been recorded in marine organisms in the region concerned two species of fish, where 2.6 and 6.6 ppm had been found in the liver (dry weight), a tunicate (5.1 ppm dry weight) and two echinoderm species (0.8 and 4.4 ppm dry weight).

During the first phase of the project on the evaluation of methylmercury in Mediterranean populations and related health hazards, hair samples from Greek and Yugoslav populations had also been analysed for selenium. In 42 Greek samples, levels of selenium ranged from 0.31 to 0.74 ppm. In 17 Yugoslav samples, levels ranged from 0.29 to 0.45.

According to the GESAMP review of potentially harmful substances relating to selenium (1985), most of which is based on the 1985 WHO Environmental Health Criteria document, the primary route of exposure to selenium in general human populations is via the diet. Of the major food groups, seafood, after organ meats, contains the largest amounts of selenium.

In the absence of any information on selenium levels in Mediterranean seafood (apart from the examples cited above), it was difficult to postulate whether any risk to humans was associated with consumption of selenium-contaminated seafood in the region. On the basis of the GESAMP review, assuming an average daily consumption of 300 g of seafood with a mean selenium concentration of 2.0 ppm, the total daily intake would be 600 mg, which would be below the lower end of the range of 700 to 7000 mg per day suggested by the WHO review on selenium as giving rise to high blood selenium levels. Considering available knowledge regarding the amount of seafood consumed by Mediterranean populations in general, it could be assumed a priori that if any risk existed, this would be confined to heavy seafood consumers, and that the occurrence and extent of such risk could only be determined following the availability of more data on selenium levels in Mediterranean seafood.

The Meeting noted that an assessment on the state of pollution of the Mediterranean Sea by selenium was scheduled for preparation by the end of 1990, and that data on levels in seafood should be available by this date.

## 9.6 Conclusions

The Meeting also briefly discussed the situation regarding other metals contained in Annex II to the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources. It was generally agreed that early reviews of existing data, both analytical and biochemical, would be extremely useful. In addition, a number of studies could be at least partially combined to avoid eventual duplication.

### 10. Environmental quality and related criteria and standards required for metal marine pollutants in the Mediterranean and associated study programmes

The Meeting took note of the emission standard for mercury which had been adopted by Mediterranean governments in 1987, as also that for cadmium, which had not yet come up for official consideration and adoption. Regarding both these and other metal marine pollutants, the Meeting felt that adverse effects on human health would, in general, only apply to exposed population groups characterized by a relatively high seafood consumption. It was envisaged, therefore, that eventual recommendations to Mediterranean governments on human health would consist of guidelines for identifying such exposed populations, and proposed advisory measures on controlling dietary intake, rather than legally binding measures of a general nature. The activities proposed for the second phase of the methylmercury project, and the expansion of such studies to cover the more important metal pollutants, would provide the necessary data for the eventual formulation of such guidelines.

### 11. Recommendations

The Meeting made the following recommendations.

- (1) WHO and UNEP should continue to accord appropriate priority to research on methylmercury in Mediterranean populations within the framework of the Long-term Programme of Pollution Monitoring and Research in the Mediterranean Sea (MED POL Phase II).
- (2) Further studies on hair mercury levels should be made in areas with high seafood consumption, and Mediterranean countries requesting these should be given all possible assistance by WHO in identifying potentially at-risk groups and, during the biological monitoring studies, in providing or securing access to the required facilities for hair analysis.
- (3) WHO, UNEP and IAEA should arrange for proper intercalibration exercises among the laboratories carrying out hair mercury analysis, and for developing and providing reference samples for both total mercury and methylmercury.
- (4) WHO should make arrangements for more comprehensive liaison between Mediterranean institutions participating in the second phase of the project and those performing similar work in other regions. Such liaison could include both common methodology to the extent possible and transfer of experience and information between different regions.
- (5) WHO should finalize the part of the methylmercury clinical studies protocol dealing with adults on the basis of the Meeting's recommendations for

updating, and arrange for its early issue. In so far as the part dealing with children was concerned, this should be further reviewed in the light of recent international findings from appropriate test batteries.

(6) Future studies in the region should include at least one test already used in other studies on the effects of intrauterine exposure to methylmercury.

(7) WHO should make available to study groups both test materials and, as necessary, training in their use.

(8) WHO, FAO and UNEP should develop guidelines for suitable preventive action to be taken after high exposure to toxic elements has been found in a population, particularly with regard to measures that could reduce the intake of such toxic elements without undue interference with the culture and lifestyle of the population in question.

(9) FAO and UNEP should endeavour to obtain as much analytical data as possible on levels of mercury and other metals in edible marine species in the Mediterranean, especially in indicated hot-spots.

(10) WHO should carry out a review of existing data from Mediterranean countries on heavy metal levels (particularly cadmium, lead and selenium) in humans, especially in so far as these apply to coastal populations, to determine whether such data could eventually be correlated with seafood consumption. In this respect, new biological monitoring activities should be encouraged.

(11) WHO, FAO and UNEP should arrange for biochemical, metabolic and toxicological investigations on cadmium compounds in bivalves within the framework of the research component of MED POL Phase II, to facilitate the re-assessment of guideline values for daily intake or for maximum cadmium levels, particularly in oysters.

(12) WHO should review the incidence, if any, of skin cancer in fishermen in the Mediterranean, and evaluate any possible link of such cancer with arsenic-contaminated seafood.

Annex 1

## REPORT ON THE RESULTS OF PHASE I OF THE PROJECT ON THE EVALUATION OF METHYLMERCURY IN MEDITERRANEAN POPULATIONS AND RELATED HEALTH HAZARDS

1. Introduction and background

1.1 A number of studies on mercury levels in marine organisms, carried out in various areas of the Mediterranean Sea up to the early 1970s, indicated that prevailing concentrations in the region were generally higher than those recorded in other seas. The same conclusion was reached with regard to other matrices in the Mediterranean marine environment. In this context, it was acknowledged that natural mercury anomalies were probably responsible for the predominant input into the Mediterranean Sea overall, although there could also be a number of areas where anthropogenic contributions were significant.

1.2 This preliminary insight into the situation, though based on relatively sparse and scattered data, gave rise to considerable concern on the part of Mediterranean governments, in view of the possible consequences arising from the consumption of mercury-contaminated seafood. This concern was accentuated by the results of some epidemiological studies which showed that certain exposed population sectors (mainly fishermen and their families) consuming above-average amounts of seafood had elevated mercury levels in both blood and hair, although no definite relationship between these levels and the manifestation of clinical symptoms was established among the sample populations studied.

1.3 In order to acquire more data with a view to obtaining a better picture of the situation, a number of activities were organized by international organizations, particularly FAO, WHO, IAEA and UNEP. Special attention was accorded to mercury in the Coordinated Mediterranean Pollution Monitoring and Research Programme (MED POL Phase I), the scientific component of the Mediterranean Action Plan adopted by the governments of the region in 1975. This programme consisted in a number of pilot projects, including one on baseline studies and monitoring of heavy metals, particularly mercury and cadmium, in marine organisms, jointly coordinated by FAO and UNEP. Thirty-three research centres from 15 Mediterranean States, 25 of which included mercury in their programme of studies, participated in this pilot project.

1.4 The results obtained from the project, which was operational from 1975 to 1981, along with those obtained from other independently conducted studies, were correlated with existing data on seafood consumption patterns in the region (assessed overall by comparing recorded catches with population numbers in the various countries), as well as with international data on the health effects of mercury, particularly methylmercury, including the provisional tolerable weekly intake (PTWI) established by the FAO/WHO Joint Expert Committee on Food Additives. This analysis gave rise to the conclusion that, according to the best available data at the time, most of the general Mediterranean population appeared to have a low methylmercury intake through the consumption of seafood, and could therefore be considered not at risk. On the other hand, it appeared equally evident that some population groups in the Mediterranean region could have an intake of methylmercury through seafood in

excess of permissible levels. One particular point of concern was the still-existing comparative lack of data, both overall and, particularly, relating to possibly exposed population groups. A UNEP/FAO/WHO meeting of experts on environmental quality criteria for mercury in Mediterranean seafood, held in Geneva from 3 to 6 November 1980, agreed that it would be difficult to evaluate health hazards in the case of such exposed population groups, owing to the very limited data available.

1.5 In the meantime, the continuing concern on the part of Mediterranean governments was expressed at both the first (Geneva, 5-10 February 1979) and second (Cannes, 2-7 March 1981) meetings of the Contracting Parties to the Convention for the Protection of the Mediterranean Sea against Pollution and its related Protocols, at which the development of environmental quality criteria applicable to edible marine organisms was strongly endorsed.

## 2. Development of the methylmercury project

2.1 Results obtained during the course of the pilot phase of the MED POL programme, together with the recommendations of several meetings, lent considerable support to carrying out an integrated monitoring and epidemiological study of methylmercury in the Mediterranean to fill the gaps in existing knowledge and, on that basis, to make a proper assessment of hazards to health from the intake of methylmercury from Mediterranean seafood, and protect those sectors of the population that could be at risk.

2.2 Activities under the responsibility of WHO within the overall framework of the Long-term Programme of Pollution Monitoring and Research in the Mediterranean Sea (MED POL Phase II), approved by Mediterranean governments in 1981, and designed to cover the period 1981-1990, include the performance of epidemiological studies with a view to finalizing environmental quality criteria for a number of chemical and microbiological marine pollutants, including mercury in seafood. To this end, a comprehensive project was formulated on the evaluation of methylmercury intake in Mediterranean populations and related health hazards. The modalities of the project were finalized at a meeting jointly convened by WHO and UNEP in Athens from 13 to 17 September 1982. The project became operational in its first or pilot phase in 1984, and was implemented by WHO within the framework of the MED POL Phase II programme in collaboration with FAO and UNEP, and in liaison with (and with considerable inputs from) the chemical safety and food safety programmes of the WHO Regional Office for Europe.

## 3. Objectives of the project

3.1 The general objective of the project on the evaluation of methylmercury in Mediterranean populations and related health hazards is to evaluate the possible hazards to the health of selected population groups arising from the methylmercury content of Mediterranean seafood.

3.2 The specific objectives are the following:

- (1) the selection of populations in the Mediterranean that have a relatively high intake of methylmercury;

- (2) the identification of groups whose methylmercury intake exceeds the PTWI established by the Joint FAO/WHO Expert Committee on Food Additives;
- (3) an estimation of the above groups':
  - (a) size
  - (b) patterns of individual consumption of seafood
  - (c) exposure to other forms of mercury
  - (d) actual concentrations of methylmercury in the various species consumed.
- (4) an assessment of methylmercury exposure in the critical segments of the population;
- (5) an investigation of methylmercury-associated abnormalities in high-risk population groups as compared to control groups.

3.3 The attainment of these objectives will significantly assist the relevant governmental authorities in the Mediterranean in the selection and formulation of regulatory action to limit the intake of methylmercury through seafood.

3.4 As the human fetus is considered to be the most sensitive target, special attention should be given to estimating the consumption of methylmercury by pregnant women.

#### 4. Activities

4.1 Preparatory activities in connection with the project consisted of the following:

- (1) the preparation of a background paper reviewing international activities on the subject;
- (2) the preliminary identification of the countries interested in participating in the project;
- (3) the identification of a number of institutions (within the countries concerned) that could carry out the various components of the project, i.e. dietary surveys, sampling and analysing edible seafood and human hair, and appropriate epidemiological studies on selected population groups (this identification was undertaken with the assistance of a number of national coordinators for MED POL);
- (4) the preparation of draft protocols for the performance of a dietary survey, the determination of methylmercury in human hair, and the conduct of epidemiological studies (these draft protocols were prepared with the assistance of various consultants).

4.2 The meeting on the evaluation of methylmercury in Mediterranean populations and related health hazards, Athens, 13-17 September 1982, during which the project was approved, achieved the following results:

- (1) an indication of criteria for determining "hot-spots" to be used as sampling areas for the studies;
- (2) development of a detailed work plan, and formulation of a revised project document;
- (3) revision of the protocols for the dietary study and for the sampling and analysis of human hair, and development of the principles underlying the epidemiological study;
- (4) agreement on the target groups to be sampled;
- (5) agreement on the modalities for carrying out the project within the overall framework of MED POL Phase II, taking into account both the aspects being implemented by the WHO Regional Office for Europe and the inputs from other parts of the programme, and also as part of the Regional Office's programme on chemical safety.

4.3 In the revised project document, as endorsed by the meeting, it was stated that the project would consist essentially of parallel studies carried out in a number of Mediterranean countries. An attempt would be made to identify, in each country, one or more appropriate study areas in the light of data resulting from:

- (1) the compilation of existing national data to permit the organization of a preliminary dietary survey on seafood consumption;
- (2) the performance of such a survey and the evaluation of methylmercury intake, based on the results of the survey and on available data on levels of mercury in seafood;
- (3) the sampling and analysis of human hair (and, whenever appropriate, of other tissues) for total mercury and methylmercury among the target populations.

4.4. To obtain reliable figures on population exposure to methylmercury, the areas selected would consist of a number of representative villages with similar fishing patterns, local ecologies and lifestyles, and could include places where elevated mercury levels had already been recorded in the MED POL monitoring programme.

## 5. First project review

5.1 The project became operational on a pilot basis in Yugoslavia in early 1984, and in Greece and Italy in 1985. The situation was extensively reviewed by a meeting on biological monitoring of methylmercury in Mediterranean populations, jointly convened by WHO, FAO and UNEP in Zagreb from 17 to 21 September 1984. The meeting recognized the fact that, while a proper assessment of high-risk population groups could only be made on the basis of relevant data, for the purposes of the project, a preliminary assessment would have to be made in the light of existing knowledge. In this regard, the data obtained during the course of the 1975-1980 MED POL Phase I pilot project on levels of mercury in Mediterranean seafood could only be treated as indicative, for the following reasons:

- (1) in the majority of cases, only a relatively small number of seafood species were analysed for mercury, and the overall picture from the geographical viewpoint was far from complete;
- (2) an enormous concentration discrepancy was encountered between different individuals of the same species, in many cases uncorrelated to age or size;
- (3) the extent to which Mediterranean consumers included seafood (fresh, frozen or canned) imported from outside the region in their diet was a major unknown factor.

With regard to consumer groups, the meeting recognized four major categories.

- (1) General populations within the region, consuming average or below average amounts of seafood, mainly caught in areas where mercury concentrations were average. This group would not be expected to exceed the PTWI of 0.2 mg methylmercury per week.
- (2) General populations, also consuming average or below average amounts of seafood (approximately 0.5 to 0.7 kg per capita per week) in areas where high mercury concentrations had been recorded. Here an average concentration of 1.2 mg/kg of mercury in seafood would result in an approximate weekly intake of 0.6 to 0.8 mg of methylmercury.
- (3) Population groups consuming higher than average amounts of seafood, or exhibiting species-selectivity in their seafood diet. Depending on the particular area, mercury concentration in seafood within the area, and type of seafood consumed, the intake of these groups could, at least in part, exceed the PTWI.
- (4) Population groups consuming higher than average amounts of seafood in areas where high mercury concentrations were found. The intake of these groups would be expected to exceed the PTWI.

5.2 All persons other than those in the first category, which could be said to constitute the large majority, could be considered to be at various degrees of risk. It was agreed that in the preliminary studies constituting the pilot phase, the best groups to concentrate on would be those known to have a high Mediterranean seafood consumption, e.g. fishermen and their families, particularly those known to consume seafood contaminated by mercury from specific natural or individual sources. Similarly, in view of the sensitivity to mercury at the prenatal stage, it was confirmed that the studies should pay particular attention to women of child-bearing age.

5.3 The matter of selection of areas for pilot study and representative population samples within these areas was reviewed, and the following criteria were agreed upon:

- (1) *Selection of area.* The area should be such as to provide environmental conditions conducive to a potentially high mercury exposure. As the study was specifically designed to give an indication of such exposure through consumption of contaminated

seafood, the main criteria for area selection would have to be the methylmercury concentration in seafood caught, processed and subject to the effects of industrial or other mercury pollution (resulting in elevated levels in all or most species) or the presence of species of seafood normally accumulating more mercury than others as a main catch.

- (2) *Selection of population sample.* Determination of the population sample would necessarily have to be a compromise between statistical significance requirements and resource availability. With the limited financial resources available for implementing the project, the actual size of the sample would have to be the minimum compatible with technical needs. The question would then arise as to whether the sample should be drawn completely at random from within the population inhabiting the area or whether it should be restricted a priori to those groups more likely to be exposed than others. In a mixed community, a random sample drawn at cross-sectoral level would afford an indication of the general situation prevailing in the area as a whole. It would, however, result in the "positive" subsample, on which the second phase (clinical studies for health effects) would be undertaken, being too small for statistical significance. Conversely, a sample drawn exclusively from those groups known to be more exposed than others would provide valuable data on the population sector requiring most attention and afford a larger sample for the clinical studies, but at the same time would only provide a partial picture of the general situation.

5.4 Taking all factors into consideration, the meeting agreed that the second alternative would be preferable in the initial phase. Furthermore, if the sample consisted of the entire population of a small fishing village, several disadvantages, including the statistical significance requirements, would be automatically removed. It was also agreed that, in addition to the "potentially high-risk sample", a control group should be similarly investigated.

5.5 It was agreed that the current studies in Yugoslavia and those planned to commence in Greece and Italy in 1985 would constitute the first phase of the project. Based on these results, the second phase could be two-pronged, involving (a) extension of the same studies to other countries, and (b) performance of clinical epidemiological studies, if so indicated.

## 6. Project implementation, 1984-1986

### Studies in Yugoslavia

6.1 The study in Yugoslavia, carried out by the Department of Nutrition, Institute of Public Health of Croatia, Zagreb (which since mid-1986 has been placed within the Institute for Endocrinology, Metabolic Diseases and Diabetes "V. Vrhovac", Medical Faculty, University of Zagreb) used two areas on the Adriatic coast: an experimental area shown by previous studies to contain relatively high concentrations of mercury in coastal waters and sediments as a result of industrial pollution in the locality, and a control area, with no industries, located at a distance of 80 km along the coast. Representative villages with similar lifestyles and fishing patterns were selected from each

area. In each village, sample populations were selected for a dietary survey on the basis of fishing activities, with full-time and part-time fishermen and their families being accorded priority; 79 families with 314 members were selected from the experimental area, and 63 families with 255 members from the control area.

6.2 A comparative study was made on mercury levels in selected seafood species in each area; 40 species were identified in the diet of families in the experimental area, and 38 in the diet of those in the control area. Both total mercury and methylmercury levels were determined in these species, those in the experimental area ranging from 0.070 to 1.370 mg/kg (total mercury) and 0.011 to 0.618 mg/kg (methylmercury). In the control area, the corresponding ranges of levels were 0.040 to 0.520 mg/kg and 0.016 to 0.508 mg/kg. The mercury content of seafood was higher in the experimental area, the difference being particularly pronounced in the case of total mercury. A considerable degree of variation was recorded among the various species in the proportion of methylmercury to total mercury, ranging from 10.1% to 105.8% in the experimental area, and from 5.3% to 106.8% in the control area.

6.3 The dietary survey was essentially conducted on the basis of the protocol developed during the September 1982 meeting in Athens. A much higher rate of seafood consumption was recorded in the control area as compared to the experimental area. In the former, 27.0% of the families surveyed consumed seafood 5 to 7 times per week, and only 3.2% were found to be consuming no seafood at all during the period. On the other hand, the corresponding figures for the latter area were 13.9% and 11.4% respectively. This difference was ascribed to the reluctance of the populations in industrialized areas to eat seafood because of industrial pollution (in the general sense, not specifically because of mercury).

6.4 On the basis of these results, it was calculated that the average weekly intake of total mercury ranged from 64.5 to 177.0 mg per person in the experimental area, and from 44.5 to 125.7 mg in the control area. In the case of methylmercury, calculated intakes were 34.5 to 90.8 mg in the experimental area, and 27.5 to 102.0 mg in the control area. A total of 46 subjects in the experimental area (14.7% of the sample) and 22 in the control area (8.6% of the sample) were calculated to have a total mercury intake above the PTWI of 300 mg. In the case of methylmercury, 20 subjects (6.4%) in the experimental area and 43 (16.9%) in the control area were calculated to have an intake of PTWI of 200 mg.

6.5 The only way in which these differences could be explained were that the higher methylmercury levels in the control population were the result of a higher consumption of seafood, together with relatively high levels of methylmercury (as a proportion of total mercury) in the species consumed.

6.6 Hair samples were taken from 42 children and teenagers (age 1-16) from each area. The samples were analysed for total mercury and methylmercury by the Department of Nuclear Chemistry Department, "Josef Stefan" Institute, Ljubljana, according to a reference method developed by the Institute for the project. Subjects from the experimental area had total mercury levels ranging from 0.10 to 5.30 ppm (with a mean of 1.75 ppm) and methylmercury levels ranging from 0.09 to 3.7 ppm (with a mean of 1.41). Corresponding levels for subjects in the control area were 0.41 to 3.8 ppm (mean : 1.73) and 0.28 to 3.6 ppm (mean : 1.37). There was very little overall difference, and no single subject had a hair methylmercury level of 4 ppm or above.

### Studies in Greece

6.7 The study in Greece, which was of a preliminary nature, was carried out jointly by the Department of Nutrition and Biochemistry of the Athens School of Hygiene, and the Institute of Child Health, Aghia Sofia Children's Hospital, Athens. Two main areas were selected - an industrial coastal town near Athens, from which families with small children were selected as a sample population, and a small non-industrial town located approximately 20 km from the sea, from which schoolchildren were selected. A simplified dietary survey, modified from the original 1982 protocol to take account of local circumstances, was conducted on a total sample of 1500 subjects from the two areas.

6.8 The survey identified 250 individuals who were found to have a seafood consumption of two meals or more per week. Out of these, it was only possible to take hair samples from 121 individuals, either because of the impossibility of collecting a sufficient quantity of hair, or because of other factors (mainly the use of selenium-containing hair lotions). Among these individuals, 36 (21 adults and 15 children) were from the industrial area, and 87 from the non-industrial area. In addition, hair samples were taken from 17 young men just drafted into the Greek Navy, all coming from fishing families from various parts of the country.

6.9 As in the case of the Yugoslav populations, hair samples were analysed for total mercury and methylmercury by the Department of Nuclear Chemistry, "Josef Stefan" Institute, Ljubljana. Total mercury levels in the hair of the 21 adults (mostly pregnant women) from the industrialized area ranged from 0.72 to 2.6 ppm. Methylmercury levels ranged from 0.25 to 1.42 ppm. The corresponding figures for the 15 children (ages 2-5) from the same area were 0.48 to 5.1 ppm and 0.37 to 1.59 ppm. In the case of the non-industrial area, the 87 schoolchildren sampled had total mercury levels ranging from 0.38 to 4.0 ppm and methylmercury levels ranging from 0.09 to 4.2 ppm.

6.10 The 17 young adults from the navy base had hair total mercury levels ranging from 0.56 to 37.51 ppm, and methylmercury levels ranging from 0.16 to 35.9 ppm. Both upper values were recorded in one individual consuming 20 seafood meals per week. None of the other subjects in this subsample had levels exceeding 5.0 ppm total mercury or 3.6 ppm methylmercury.

6.11 As in the case of the Yugoslav study, the levels of total mercury and methylmercury in hair were generally similar in both "exposed" and "non-exposed" population samples. In both areas, children had higher levels.

### Studies in Italy

6.12 A number of studies on the health effects of mercury ingested through seafood consumption have been conducted in Italy on various sample populations during the last decade. The review, however, was conducted only on the current project study, which had only been in operation for a few months.

6.13 Three areas on the coast of the Tyrrhenian Sea had been selected, one with mercury pollution due to industry, another with high mercury levels due to volcanic activity in the vicinity, and the third with fishermen spending at least 7 months a year at sea.

6.14 Thirteen seafood species were identified as being regularly consumed by fishing families in the first area. The total mercury content of these species ranged from 0.180 to 1.190 mg/kg. A preliminary dietary survey on 58 of the families revealed that the heavy consumers were the fishermen themselves who ate four to eight seafood meals per week rather than the wives and children, who ate only up to three. Up to the time of the report, the hair of seven fishermen from this station had been analysed by the Department of Nuclear Chemistry, "Josef Stefan" Institute, Ljubljana. Levels of total mercury ranged from 3.58 to 29.66 ppm total mercury (mean : 16.03 ppm) and from 3.45 to 25.31 ppm methylmercury (mean : 13.28 ppm).

6.15 The dietary survey and seafood analysis components in the studies on the other two areas were still in progress at the time of reporting, and no numerical results were therefore available. A number of people being interviewed in the area subject to mercury liberation into the sea as a result of volcanic activity were recorded as consuming four seafood meals or more per week. Similarly the ongoing survey of fishermen in the third area (spending seven months a year on board their vessels) showed that these were consuming a minimum of seven seafood meals per week.

6.16 As a comparison, the hair of 19 subjects living inland, and considered as average non-seafood-eating persons following a simplified dietary survey, was sampled - giving results in the range of 0.26 to 2.97 ppm (mean : 1.12 ppm) total mercury, and 0.17 to 2.10 ppm (mean : 0.77 ppm) methylmercury.

#### Overall progress and medium-term results

6.17 The data from the studies made it possible to compare the different approaches which, while conforming to the same overall plan, varied in a number of specific details according to national conditions. In all these countries, selection of test areas was based on industrialization and the consequent pollution of the sea by mercury. In Italy, a non-industrialized area, nevertheless having high mercury levels due to natural sources (volcanic activity), was also selected. The areas of comparison differed slightly in that the Yugoslav control area was non-industrialized and slightly less polluted, while the Greek and Italian control areas were both inland, with the Italian area being selected on the basis of non-consumption of seafood.

6.18 Both in Italy and in Yugoslavia, analysis of seafood for total mercury and methylmercury content commenced simultaneously with the other project components. In Greece, this was omitted from the initial pilot phase. Population samples for the dietary survey and hair analysis were all based on a highly selective approach, pinpointing fishermen and their families as the main target group, either in all areas or at least in the test area. The questionnaires used in the dietary survey varied somewhat in degree of elaboration and in content - in Greece, for instance, the same degree of emphasis was placed on consumption of non-seafood items to avoid misinterpretation of the situation leading up to the performance of the project. Subjects for hair analysis within the dietary survey groups were selected either (where consumption of seafood was combined with seafood mercury levels) on the basis of a calculated excess of intake over the PTWI, or on the basis of amounts of seafood consumed.

6.19 The overall averages of methylmercury levels in seafood were twice as high in Italy as in Yugoslavia. Regarding the proportion of methylmercury to total mercury in seafood, the studies in Italy and Yugoslavia confirmed that

this varied to a considerable extent with particular species, and that risks were, to a not inconsiderable extent, associated with consumption of particular species, not only with regard to bioaccumulation capacity but also with regard to methylmercury proportions within the total mercury levels.

6.20 During 1984-1986 a total of 250 samples of human hair from all three countries were analysed for total mercury and methylmercury. In addition levels of selenium were determined in 25% of these samples. In general, methylmercury levels in the hair of Greek and Yugoslav subjects (irrespective of area) and of "non-exposed" Italian subjects were, with one exception, lower than 4 ppm. This appeared to indicate that the varying degrees of mercury pollution in Greece and Yugoslavia did not result in significant differences in concentrations found in the hair.

6.21 In the case of the two groups composed exclusively of fishermen, the hair samples from the seven Italian subjects showed high levels of methylmercury (two above 4 ppm and four above 10 ppm), but, with one exception (36 ppm in the person recorded as consuming 20 seafood meals per week), low levels were found in the samples from the 17 Greek subjects. Although the differences between the two groups could not be explained at the time on the basis of the present interim data available, an extremely high consumption of seafood was the only common feature linked with high methylmercury levels in the hair, regardless of country.

6.22 The overall results are summarized in Table 1. The figures for the different countries are not directly comparable, owing to the variation in exposure conditions (pollution levels, and amount of seafood consumed). Out of the total number of 250 hair samples analysed, only five were recorded as having methylmercury levels above 10 ppm, and all these were from fishermen. It was, however, significant that, out of the seven fishermen from Italy, four had levels above 10 ppm, and another two above 4 ppm.

6.23 The results obtained in the project so far revealed no other cases of high exposure. This confirmed that a highly selective approach to a large population was necessary to identify potential groups at risk in the Mediterranean area.

## 7. Mid-term project review

7.1 The results summarized in section 6 above were comprehensively reviewed at a meeting on health effects of methylmercury in the Mediterranean area, jointly convened by WHO, FAO and UNEP in Athens from 15 to 19 September 1986, which also discussed institutional and other arrangements for the possible extension of current studies to other areas, and also the commencement of the clinical epidemiological work, which together would constitute phase II of the project.

Table 1. Overall summary of hair mercury determinations as related to exposure (1984 - 1986)

Country	Dietary survey	Exposure conditions				Mercury levels in hair			Risk Groups	
		Area	Seafood meals	Population sector	No. of samples	Concentration Range		Total mercury	Methylmercury	No. of samples
						4-10 ppm Me Hg	10 ppm Me Hg			
Greece	n = 1500 simplified questionnaire	Non-polluted (fishermen)	4+/week	M	17	0.56 - 38.0	0.16 - 36.0	0	1	
		Non-polluted	2 /week	F	87	0.38 - 4.0	0.09 - 4.15	1	0	
		Polluted	2 /week	M	2	0.98 - 1.16	0.62 - 1.00	0	0	
				F	19	0.69 - 2.60	0.25 - 1.42	0	0	
		Polluted (fishermen)	4+/week	Ch.	15	0.48 - 5.10	0.37 - 1.59	0	0	
				M	7	3.58 - 29.66	3.45 - 25.31	2	4	
Italy	n = 200 simplified questionnaire	Polluted	2+/week	F	-	-	-	-	-	
		Non-polluted control	0 /week	M	19	0.26 - 2.97	0.17 - 2.10	0	0	
				F	-	-	-	-	-	
		Non-polluted	0-7/week	Ch.	-	-	-	-	-	-
			av. 2-3	M	-	-	-	-	-	-
		Polluted	0-7/week	F	42	0.41 - 3.80	0.28 - 3.60	0	0	
av. 3-5	Ch.		-	-	-	-	-	-		
Yugoslavia	complete questionnaire	Polluted	0-7/week	M	42	0.10 - 5.30	0.09 - 3.70	0	0	
			F	-	-	-	-	-		
TOTAL	2269				250			3	5	

7.2 On the basis of results obtained so far, the meeting recognized that one of the groups at highest risk in the region was adult fishermen, mainly those who spend a significant proportion of their time at sea, and whose main source of food during this period is fish. Considering that mothers of newborn infants (particularly, but not necessarily, if they come from fishing families) constitute a recognized high-risk group, the meeting agreed that immediate follow-up activities within the project should aim at identifying individuals within these two target groups with high methylmercury levels in their hair. This would show whether such groups were large enough to establish a relationship between exposure to methylmercury and impairment of the central nervous system.

7.3 It was therefore agreed that the programme for the remainder of the first phase, which would involve 500 hair samples each from Greece, Italy and Yugoslavia, would include the following:

- selection of areas with a high probability of population groups consuming seafood, such as islands and coastal areas;
- selection of individuals consuming a large amount of seafood (at least three meals per week for mothers with newborn infants, and four meals per week for adult fishermen);
- sampling of hair according to the procedure described in the reference method;
- analysis of hair for total mercury, and identification of mothers with newborn infants with levels exceeding 6 ppm and adult men with levels exceeding 25 ppm;
- analysis of hair for levels of methylmercury in the case of individuals exceeding these thresholds;
- compilation of extensive information on food consumption patterns (particularly the amount and type of seafood consumed) in the case of the individuals so identified, together with data on methylmercury levels in seafood, in order to identify the source of methylmercury in groups at high risk;
- assessment of the data obtained to evaluate the size of population groups with elevated mercury levels, and establishment of the feasibility of undertaking a clinical epidemiological study.

7.4 The centralization of hair analysis in one laboratory precluded the need for interlaboratory intercalibration exercises, and the "central" laboratory had its own quality control programme. Emphasis was placed on the importance of all participating institutions performing the sampling of hair according to the procedures laid down in the protocol. Following a brief discussion of some of the problems involved, the section on hair sampling by the appropriate reference method was modified slightly to provide a more precise classification and to ensure more complete adherence to it.

7.5 The possible expansion of the first phase studies to include other Mediterranean countries (in addition to the present three) was discussed. Although this was seen as highly desirable on technical grounds, one particular problem was that of finance, since there was very little possibility of increasing the present total level of assistance to participating laboratories, either currently or in the near future. It was agreed that steps should be taken to attempt to increase the present financial allocation for the project.

7.6 After considering similar projects in other areas, the meeting concluded that coordination and cooperation with such projects was highly desirable. It also appeared feasible that the immediate follow-up work in the Mediterranean could share some basic components with related programmes in other areas.

7.7 The meeting made the following recommendations regarding future work in the implementation of the project.

- (1) The aim of the eventual epidemiological study in the Mediterranean, if feasible, should be to measure the effects of exposure of fishermen to methylmercury by means of a cross-sectional study on adults, and to measure the effects of prenatal exposure of children by means of a follow-up study.
- (2) The follow-up activities of the present pilot phase should, if possible, include testing, training and harmonization of the examinations indicated in the protocol of the epidemiological study.
- (3) WHO, FAO and UNEP should ensure that an adequate financial allocation from the MED POL budget is made available for continuing the pilot phase of the project. This should include the geographical extension of the project through performance of the preliminary components in other Mediterranean countries.
- (4) Endeavours should be made to obtain other financial resources from both national and international sources to ensure coverage of later stages of the project.
- (5) In view of the need to investigate further the problem of neurotoxicity in children, a working group should perhaps be convened to develop a core battery of neurodevelopmental tests for infants and preschool children for use in epidemiological studies.

## 8. Implementation of studies, 1986-1988

8.1 The studies were continued from late 1986 up to mid-1988, in accordance with the basic strategy and major principles postulated by the 1986 Athens meeting. Major attention was focused on pregnant mothers (as the most sensitive) and fishermen (as the most exposed). Hair samples were also taken, however, from women who, though not pregnant at the time, were of child-bearing age, children up to 19 years (divided into two age groups, 0-5 and 6-19), older women in high seafood consumption areas and non-seafood-consumers as controls.

8.2 In each case, for correlation purposes, the amount of seafood consumed was assessed, generally through a simplified dietary questionnaire.

8.3 By the end of July 1988, an additional total of 848 hair samples had been analysed for total mercury; 519 of these were from Greece, 215 from Italy and 114 from Yugoslavia. In accordance with the recommendations of the 1986 Athens meeting, hair samples from pregnant women and from children which contained 6 ppm total mercury, as well as from adults containing more than 25 ppm total mercury, were also analysed for methylmercury. In all, 180 hair samples were analysed for methylmercury - 56 from Greece, 90 from Italy and 34 from Yugoslavia. As a number of samples below the limits of 6 ppm and 25 ppm were also analysed for methylmercury, the number of analyses performed does not correspond exactly to the number of samples in which the relative limit was exceeded.

#### Studies in Greece

8.4 A total of 519 individuals had their hair analysed for mercury in two separate studies. In the first, carried out by the Institute of Child Health, Aghia Sophia Hospital, Athens, 249 individuals were selected mainly from the isolated fishing village of Trikkeri, where fresh local seafood, mainly caught from the open waters of the Aegean Sea, is a major constituent of the diet, and from the neighbouring town of Volos, from the Thessaloniki area (including the village of Nea Michainiona) and from Chalkis.

8.5 In a total population sample of 46 new mothers (i.e. women with newborn babies) in Trikkeri, Thessaloniki and Chalkis, the range of hair mercury (expressed as Hg-T) was 0.08 to 14.3 ppm. Two subjects (4.35%) had levels above 6 ppm, and their methylmercury levels, which were also determined, were 9.14 and 4.85 ppm. Another 56 females of child-bearing age (16-45 years) had hair mercury (Hg-T) levels ranging from 1.13 to 18.4 ppm; and 8 (14.3%) were above 6 ppm. In the latter, the hair methylmercury content ranged from 2.4 to 15.4 ppm. A total of 32 other women over 45 years of age, also from Trikkeri, had hair mercury (Hg-T) levels ranging from 1.22 to 16.3 ppm. The methylmercury hair levels of the eight with over 6 ppm total mercury ranged from 2.22 to 8.99 ppm.

8.6 In Trikkeri, the total mercury content of 25 children, aged 5 years and below, ranged from 1.06 to 15.7 ppm. Five children (20%) had levels above 6.0 ppm, and two (8%) levels above 14 ppm. Corresponding hair methylmercury levels for these five children ranged from 4.95 to 13.6 ppm. In 35 children aged 6-19 years, the total mercury levels in hair ranged from 1.31 to 15.3 ppm. In seven of these subjects, methylmercury levels ranged from 3.72 to 11.7 ppm.

8.7 Altogether 37 adult fishermen from Trikkeri and Volos had total mercury in hair ranging from 0.57 to 50.2 ppm. In five of them (13.5%), levels were above 25 ppm, and their corresponding methylmercury levels ranged from 21.8 to 35.6 ppm. In another three members of the same population, the hair methylmercury level was above 10 ppm. A further 17 subjects taken as controls gave total mercury levels ranging from 0.47 to 12.6 ppm.

8.8 The second study was carried out by the Department of Nutrition and Biochemistry of the Athens School of Hygiene. Hair samples were collected from 270 women delivering their babies in four hospitals, two in the Athens area (central Athens and Egaleo) and two in Corinth. In 50 subjects from Alexandras Hospital, Athens, the range of total mercury concentrations in hair was 0.20 to 2.04 ppm; in 13 subjects from Corinth, 0.30 to 2.17 ppm; in 138 subjects from Egaleo, 0.28 to 14.60 ppm; and in 69 subjects from the second Corinth Hospital, 0 to 9.00 ppm. Out of the 138 subjects from Egaleo, four had total mercury hair levels of above 6 ppm, with corresponding methylmercury levels ranging from 0.26 to 1.15 ppm, while out of the 82 subjects from Corinth, one had a total mercury level above 6 ppm, with a corresponding methylmercury level of 0.47 ppm.

8.9 The levels of mercury recorded were higher than in the first study phase. A clear correlation was found between the number of fish meals per week and the hair mercury levels in all the subgroups.

#### Studies in Italy

8.11 The findings of the Italian study, for which only preliminary results had been available at the Athens meeting in September 1986, were consolidated. A total of 241 hair samples were collected and analysed from three population samples comprising:

- (1) 151 adult fishermen from the towns of Porto San Stefano, Porto Ercole and Orbetello on the Argentario promontory in the Tyrrhenian Sea area, consuming an average of more than four seafood meals per week (mainly fish);
- (2) 44 pregnant women from the same area, all from fishing families, consuming an average of 2-3 seafood meals per week;
- (3) 46 adult males from control areas (inland towns in the same general geographical area as the other two samples), consuming one or less seafood meals per month.

8.12 This population included the 26 (7 fishermen and 19 controls) covered in 1986. Samples were collected from more than 30 other subjects, but the results still await analysis.

8.13 In the first population (adult fishermen), the levels of total mercury in hair ranged from 1.09 to 66.90 ppm. A total of 33 samples (21.85%) had levels above 25 ppm and these, together with 60 other samples with levels generally above 6 ppm were also analysed for methylmercury. Levels ranged from 0.94 to 52.50 ppm, and in 60 cases (39.73% of the total population sample of 151) were above 10 ppm.

8.14 In the second population (pregnant women), the levels of total mercury in hair ranged from 0.53 to 15.60 ppm, and in seven cases (15.91%) were above 6 ppm. Hair methylmercury was only measured in three cases, the levels recorded being 2.66, 4.82 and 8.78 ppm.

8.15 In the third population (male non-seafood-consuming controls), levels of total mercury in hair ranged from 0.06 to 7.31 ppm.

8.16 As in the Greek study, levels of hair mercury gave a very good correlation with amounts of seafood consumption. From the latter point of view, the results from the three populations were relatively clear-cut. The high levels of mercury (both total and methylmercury) confirmed the trend indicated in the first results of the analyses submitted in 1986.

#### Studies in Yugoslavia

8.17 The Yugoslav studies were directed at women giving birth in various hospitals along the Adriatic coast. By the end of July 1988, analytical results were available for hair samples from 114 women - 68 from coastal towns and villages, 34 from islands in the central Adriatic Sea, whose babies were delivered at the Maternity Hospital in Split, and 12 controls, also mothers with newly born babies, living in areas where no pollution was recorded. The majority of these consumed two to three seafood meals per week.

8.18 In the first population sample of 80, the range of total mercury levels in hair was from 0.21 to 5.42 ppm. None of these samples were analysed for methylmercury as all were below the agreed limit of 6 ppm. Total mercury levels in the second group ranged from 0.42 to 3.28 ppm. Though these values were low, all the samples were also analysed for methylmercury, the range recorded being from 0.19 to 3.12 ppm. In the reference sample population, the range of total mercury in hair was from 0.25 to 1.12 ppm.

#### Summary of results

8.19 An overall summary of the results obtained during the 1986-1988 period is given in Table 2. From these results, it would appear that the most affected group consists of adult fishermen. Women of child-bearing age who are relatively high seafood consumers could be considered as equally at risk, because of the greater sensitivity of the fetus. The position of young children should also be considered.

### 9. General summary and conclusions

9.1 In Greece, results of hair analysis for mercury indicated no risk to the general population. However, those individuals who reported higher seafood consumption tended to have higher mercury concentrations. A total of 659 hair samples were analysed. In the initial part of the study, 17 fishermen from various parts of Greece, consuming more than four seafood meals per week, were sampled, together with 21 adults and 15 children from an industrially polluted area, and 87 children from a non-polluted area, the latter two groups consuming two seafood meals per week and having hair mercury concentrations ranging from 0.38 to 5.10 ppm. In the second part of the study, 5 out of 37 fishermen had concentrations between 25 and 50 ppm; while 64 women aged 16 to 45 living in the isolated fishing community of Trikkeri, who reported a consumption of three or more seafood meals per week, had concentrations from 1.13 to 18.4 ppm (median 4.11 ppm) and above 6 ppm in eight cases. In the same village, the concentrations in 59 children below the age of 19 years ranged from 1.06 to 15.7 ppm (median 3.75 ppm) and were above 6 ppm in 12 cases. Samples were also taken from 276 pregnant women delivering

Table 2. Overall summary of hair mercury determinations as related to exposure 1986-1988

Country	Exposure conditions		Mercury levels in hair				Risk groups (no. of samples)					
	Area	Seafood meals per week	Population sector	Total mercury		Methylmercury		Total mercury				
				No.	Conc. range	No.	Conc. range	6 ppmt	25 ppmt	4-10 ppm	10 ppmt	
Greece	Non-polluted	3 - 7	M (fish)	37	0.57 - 50.20	5	21.80 - 35.60	-	5	0	5	
			M (non-fish)	12	0.94 - 10.60	1	2.98	-	0	0	0	
			F (nm)	46	0.08 - 14.30	2	4.85 - 9.14	2	-	2	0	
			F (16-45)	43	1.13 - 18.40	13	2.40 - 15.40	13	-	8	3	
			F (45+)	51	0.47 - 16.30	8	2.22 - 8.99	8	-	4	0	
			CH(0-5)	25	1.06 - 15.70	5	4.95 - 13.60	5	-	3	2	
			CH(6-19)	35	1.31 - 15.30	7	3.72 - 11.70	7	-	5	1	
Various	1 - 7	F (nm)	276	0.00 - 14.60	5	0.26 - 1.15	5	-	0	0		
Italy	Polluted Non-coastal	4 - 7 2 - 3 0 - 1	M (fish)	151	1.09 - 66.90	93	0.94 - 52.50	-	33	26	60	
			F (nm)	44	0.53 - 15.60	3	2.66 - 8.78	7	-	2	0	
			M	46	0.06 - 7.31	0	-	-	0	0	0	
Yugoslavia	Polluted (coastal)	2 - 3	F (nm)	68	0.21 - 5.42	0	-	0	-	0	0	
			Polluted (islands)	2 - 4	F (nm)	34	0.42 - 3.28	34	0.19 - 3.12	0	-	0
					Non-polluted	2 - 4	F (nm)	12	0.25 - 1.12	0	-	0

their babies in four hospitals (two in Athens and two in Corinth) with varying fish consumption patterns, and concentrations were found of 0.00 to 14.60 ppm and above 6 ppm in five cases.

9.2 In Italy a total of 241 hair samples were analysed, 151 from fishermen in an area close to cinnebar deposits, consuming over four seafood meals per week, 46 from pregnant women in the same area, consuming two to four seafood meals per week, and 46 from a control area (an inland town), consuming less than one seafood meal per week. In the first population sample, hair mercury levels ranged from 1.09 to 66.90 ppm, while 60 were above 25 ppm. In the second group (pregnant women), levels ranged from 0.06 to 7.31 ppm. Among the whole population sampled, levels of over 25 ppm were only recorded in the case of fishermen spending extended periods of time at sea.

9.3 In Yugoslavia the results of hair analyses of 198 subjects, drawn from the general populations of two areas, and from pregnant women delivering their babies in four hospitals, all along the Dalmatian coast, showed no individuals at risk. Hair mercury levels of 42 children from an industrially polluted area, with an average seafood consumption of two to three meals per week, ranged from 0.10 to 5.30 ppm, while those of 42 children from a non-polluted area, with an average consumption of three to five seafood meals per week, ranged from 0.41 to 3.80 ppm. In 114 pregnant women delivering their babies in four maternity hospitals, the range of hair mercury levels was 0.21 to 5.42 ppm.

9.4 The results of the study confirmed that there is a positive correlation between seafood consumption and levels of total mercury and methylmercury in hair. On the basis of the criteria detailed above, no at-risk individuals were identified in the Yugoslav survey. In the Greek population evaluated, there was no evidence of risk to the large majority, but some concentrations in residents of isolated fishing communities consuming very large amounts of seafood, including fishermen and women of child-bearing age, exceeded the criteria. The majority of the Italian population surveyed were also considered as free from risk, the at-risk groups being high seafood consumers such as fishermen spending considerable amounts of time at sea, and babies who had high-level intrauterine exposure from maternal seafood consumption.

Annex 2

LIST OF PARTICIPANTS

TEMPORARY ADVISERS

- Mr Sadok Atallah  
Director, Environmental Health and Environmental Protection, Ministry of  
Health, Tunis, Tunisie
- Dr Angelo Bortoli  
P.M.P. Environmental Health Section, Venice, Italy
- Dr Shmuel Brenner  
Research Institute for Environmental Health, Medical School, Tel-Aviv  
University, Tel-Aviv, Israel
- Professor Ratko Buzina  
Institute for Diabetes, Endocrinology and Metabolic Diseases "Vuk  
Vrhovac", Medical Faculty, University of Zagreb, Zagreb, Yugoslavia
- Dr Anthony R. Byrne  
Department of Nuclear Chemistry, "Josef Stefan" Institute, Ljubljana,  
Yugoslavia
- Dr Aharon Eisenberg  
Public Health Services, Ministry of Health, Jerusalem, Israel
- Professor Renato Gilioli  
Institute of Occupational Health, L. Devoto Clinic, Milan, Italy
- Dr Stefan Halbach  
Association of Radiation and Environmental Research, Institute of  
Toxicology, Neuherberg, Federal Republic of Germany
- Ms Milena Horvat  
Department of Nuclear Chemistry, "Josef Stefan" Institute, Ljubljana,  
Yugoslavia
- Dr Larbi Idrissi  
National Institute of Public Health, Ministry of Health, Rabat, Morocco
- Dr Jan Jurij  
Pesticide Laboratory, University Institute of Health Care and Social  
Welfare, Ljubljana, Yugoslavia
- Dr Alfred Kobal  
Department of Nuclear Chemistry, "Josef Stefan" Institute, Ljubljana,  
Yugoslavia
- Dr Manuel Mariño  
Department of Sanitary Engineering, National School of Health, Ciudad  
Universitaria, Madrid, Spain

Dr David O. Marsh

Department of Neurology, University Medical Centre, Rochester, United States

Professor Berislav Momcilovic

Department of Occupational Health and Toxicology, Institute for Medical Research and Occupational Medicine, Zagreb, Yugoslavia

Professor Giorgio Moretti

Faculty of Medicine and Surgery, Institute of Hygiene, University of Padova, Italy

Dr Sheena Nakou

Institute of Child Health, Aghia Sophia Children's Hospital, Athens, Greece (Rapporteur)

Professor Phu-Lich Nguyen

Department of Hygiene, University of Paris-Nord, France

Professor Bruno Paccagnella

Unit for Epidemiology and Community Medicine, Department of Paediatrics, University of Padova, Italy (Chairman)

Professor Jerzy Kazimierz Piotrowski

Department of Toxicological Chemistry, Institute of Environmental Research and Bioanalysis, Lodz, Poland

Professor Aristeo Renzoni

Department of Environmental Biology, University of Siena, Italy

Dr Massimo Riolfatti

Institute of Hygiene, University of Padova, Italy

Dr Saadallah Shawaf

Department of Water Pollution Control, Ministry of Irrigation, Damascus, Syria

Dr Peter Stegnar

Department of Nuclear Chemistry, "Josef Stefan" Institute, Ljubljana, Yugoslavia (Vice-Chairman)

Dr Yves Thibaud

IFREMER Centre, Department of Environment and Ocean Research, Nantes, France

Dr Pal Weihe

Occupational Health Clinic, Torshavn, Faroe Islands, Denmark

Mr Tomislav Zvonaric

Institute of Oceanography and Fisheries, Split, Yugoslavia

REPRESENTATIVES OF OTHER ORGANIZATIONS

Food and Agriculture Organization of the United Nations (FAO)

Mr C.P. Gabrielides

Senior Fishery Officer (Marine Pollution), FAO Project Office,  
Co-ordinating Unit for the Mediterranean Action Plan, Athens, Greece

International Atomic Energy Agency (IAEA)

Dr K. Lum, International Laboratory of Marine Radioactivity, Monaco

United Nations Environment Programme (UNEP)

Mr A. Manos

Co-ordinator, Coordinating Unit for the Mediterranean Action Plan,  
Athens, Greece

WORLD HEALTH ORGANIZATION

Regional Office for Europe

Dr L.J. Saliba

Senior Scientist, WHO/EURO Project Office, Coordinating Unit for the  
Mediterranean Action Plan, Athens, Greece (Secretary)

Ms M.Y. Rollo

Secretary, WHO/EURO Project Office, Coordinating Unit for the  
Mediterranean Action Plan, Athens, Greece

Headquarters

Dr T. Kjellström

Prevention of Environmental Pollution, Division of Environmental Health,  
Geneva, Switzerland

International Agency for Research on Cancer (IARC)

Dr Alexander Chalkias

Unit of Field and Intervention Studies, Lyon, France