منظمة الأغذية والزراعة للأمم المتحدة
联合国粮食及农业组织
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION

FIR/MEDPOL/SP/25

21 NOVEMBER 1990

REPORT OF THE FAO/UNEP/IAEA CONSULTATION MEETING ON THE ACCUMULATION AND TRANSFORMATION OF CHEMICAL CONTAMINANTS BY BIOTIC AND ABIOTIC PROCESSES IN THE MARINE ENVIRONMENT

La Spezia, Italy, 24-28 September 1990

(Organized within the framework of the MED POL - Phase II programme)

PRELIMINARY

In cooperation with:

UNEP IAEA

Athens, 1990

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INTRODUCTION

The present Consultation Meeting on the Accumulation and Transformation of Chemical Contaminants by Biotic and Abiotic Processes in the Marine Environment was jointly convened by FAO, UNEP and IAEA in the framework of the Long-term Programme for Pollution Monitoring and Research in the Mediterranean (MED POL - Phase II) which constitutes the scientific and technical component of the Mediterranean Action Plan. One of the main objectives of the MED POL programme is to generate information that can be used for the progressive technical implementation of the Land-based Sources Protocol which has already been ratified by almost all of the Mediterranean States. The study of the transformation of the chemical substances in the marine environment is essential for understanding their biogeochemical cycles and their fate is one of the criteria considered when taking management decisions for marine pollution control.

Following a kind invitation by ENEA the meeting took place at the Marine Environment Research Centre of Santa Teresa near Lerici, La Spezia, Italy, from 24-28 September 1990. It was attended by 30 participants from France, Greece, Israel, Italy, Spain, Syria, Tunisia, Turkey, U.K., U.S.A. and Yugoslavia as well as by representatives of the Food and Agriculture Organization of the United Nations and the International Atomic Energy Agency. The list of participants appears as Annex I.

1. OPENING OF THE MEETING (Agenda item 1)

The meeting was opened by Mr. G.P. Gabrielides, FAO Senior Fishery Officer (Marine Pollution), on behalf of the Food and Agriculture Organization of the United Nations and the Co-ordinating Unit for the Mediterranean Action Plan, and by Mr. M. Bernhard on behalf of the Director of the host Institution. After welcoming the participants and thanking the local organizers for accepting to host the meeting, Mr. Gabrielides outlined the importance of studying the environmental transformation of chemical substances in marine pollution work and expressed the wish that the meeting would motivate and encourage Mediterranean scientists who now limit their studies to concentration levels to give more emphasis to transformations.

Mr. Bernhard welcomed the participants and expressed his satisfaction that the meeting was hosted by his Institution. He briefly explained ENEA's activities and the involvement of the Centre in the MED POL programme.

2. BACKGROUND AND SCOPE (Agenda item 2)

Mr. Gabrielides outlined the background and scope of the meeting. In doing so, he referred to the previous MED POL activities in this field and specifically to the old research activity K "Biogeochemical cycle of selected pollutants". A number of research projects are now under way in Mediterranean Institutions in the framework of Research Area IV "Fates/Environmental transformation" of the MED POL programme and the present meeting provides a forum for the principal

investigators of these projects to present their work. In addition, the meeting will give an opportunity for an exchange of views on the problems encountered by scientists working internationally in this field. Finally, the meeting will be required to make recommendations for future research needs.

3. ELECTION OF OFFICERS (Agenda item 3)

The meeting unanimously elected Mr. Michael Bernhard, Scientific Adviser at ENEA, as Chairperson, Mr. Michael Scoullos, Professor at the University of Athens, as Vice-Chairperson and Mr. James Lamond, Research Scientist at the Napier Polytechnic, Edinburgh, Scotland (presently at University of Crete, Greece) as Rapporteur. Mr. Gabriel P. Gabrielides, FAO Senior Fishery Officer (Marine Pollution) at the Coordinating Unit for the Mediterranean Action Plan, acted as Technical Secretary of the meeting.

4. ADOPTION OF THE AGENDA (Agenda item 4)

The provisional agenda as proposed by the Secretariat was accepted without modifications. It appears as Annex II.

5. ORGANIZATION OF THE WORK (Agenda item 5)

The meeting decided to work in plenary but break up into two groups for the discussion of agenda item 7. The working hours were agreed to be 09:00-13:00 hrs for the morning session and 14:30-17:30 hrs for the afternoon session. Thursday afternoon was reserved for the writing up of the report.

6. PRESENTATION OF PAPERS (Agenda item 6)

During the meeting 23 papers were presented covering various aspects of the accumulation and transformation of chemical contaminants by biotic and abiotic processes in the marine environment. The list of papers presented appears in Annex III.

The key-note paper outlining the current status, trends and prospects of chemical and biotic transformations of marine contaminants was presented by Mr. F.E. Brinckman, of the U.S. National Institute of Standards and Technology.

The importance of the ability to analytically determine both very low concentrations (10^{-15} molar) and rapidly reacting chemical species in future research was stressed in conjunction with the recognition of the need for a predictive capability in such environmental interactions with respect to both abiotic and biotic components.

Subsequent papers highlighted aspects of environmental transformations of mercury/methylmercury, TBT, aromatic and chlorinated hydrocarbons and surface active substances as well as biotic and abiotic interactions of a range of heavy metals.

All papers presented at the meeting will be published in the proceedings.

7. THE ROLE OF TRANSFORMATION AND BIOACCUMULATION OF CHEMICAL CONTAMINANTS IN THE MARINE ENVIRONMENT VIS-A-VIS POLLUTION CONTROL (Agenda item 7)

In discussing the definition of transformation several types of transformations were identified. It was agreed that the term transformation should encompass not only changes in molecular structure but also changes in the physical matrix and the medium in which a chemical entity is found. Such matrices can include not only inorganic fluvial and airborne particulates but also dissolved and particulate organic matter, living organisms such as phytoplankton and zooplankton and biogenic materials. The term "medium" can be understood to include freshwater, oxic and anoxic seawater, the gastrointestinal tracts of biota and even physiological fluids and cell cytoplasm. The recalcitrance of organic groups such as PCBs, pesticides and detergents arising from anthropogenic activities and interacting within these media was identified as a problem occurring largely at localised pollution zones with mainly lower-level 'disturbances' arising on a global level.

The meeting recognised the difficulty of treating separately biotic and abiotic transformations since they are often indistinguishable in nature but it was agreed that an attempt should be made to differentiate between the two in the discussions and in this report. Similarly the need to distinguish between man-made contaminants and elevated occurrences of natural materials was recognised, as was the importance of interfaces in acting as sites for adsorption and desorption between biotic and abiotic phases.

7.1 Biological transformation of contaminants

Both active and passive processes were identified whereby biota can mediate contaminant transformation. Contamination is essentially a matter of degree; many metals are required by living organisms for biological processes e.g. iron for oxygen and electron transport, cobalt in vitamin B_{12}, zinc in DNA and in enzymes, calcium, sodium and potassium in muscle and nerve tissues. When present in excessive amounts such metals can become toxic and need to be classified as contaminants. Degradation of organic contaminants by the biotic phase was defined as the alteration of the chemical structure of a contaminant leading to partial or complete decomposition of the parent compound.

It was recognised that, in the case of certain chemical species such as PAH, the production of mutagenic metabolites increases the need for assessment of the significance of their production, presence and removal.

a) Alteration of environment by biota

Biota can indirectly mediate contaminant transformation by altering their environment e.g. during algal blooms anoxic conditions can build up in the water column due to excessive oxygen consumption.

Excretion of waste products, such as carbon dioxide and ammonia, can directly influence contaminant speciation through changes in pH, etc. Phytoplankton are known to excrete complex molecules such as sugars and polysaccharides into their medium. Such exo-metabolites can complex metals and may render them more or less bioavailable to other organisms. The important part played by organic material associated with the particulate phase, incorporating ranges of particle size distributions, is of prime importance in determining biotic and abiotic interactions.

b) Physical interactions

Biota can also mediate contaminant transformation by providing reactive surfaces where metals and organics may be adsorbed. Such biota can also transport contaminants to depth and sea-bottom sediments. In this respect the inclusion of deep-sea areas in pollution studies is necessary.

One biological activity which is particularly important in contaminant transformation is the accumulation of contaminants which are associated with particulate matter (whether inorganic or organic) by filter-feeders and grazers. These organisms serve, by ingesting small particulates and by producing rapidly-sinking fecal pellets, not only to transform the physical matrix and perhaps the chemical structure of the contaminant, but also to transport rapidly the contaminant to depth. During their passage through the water column, associated metals can be remobilised by physical disaggregation of the pellet, by leaching and dissolution, and by biological activity in the pellet matrix. Such sinking pellets are also very efficient scavengers of contaminants and have been shown to remove metals and organics from the water column, through which they fall, and to deliver them to bottom sediments.

c) Metabolism

Perhaps the major role of biota in contaminant transformation is through metabolism. The meeting agreed that a need exists for more detailed scientific knowledge on the metabolism by organisms of persistent organic contaminants including PCBs, PAH and pesticides. As far as metals are concerned, simple chemical reactions such as methylation, demethylation, oxidation and reduction tend to be very important. Several such examples were discussed including the methylation of mercury and arsenic, the solubilization of non-toxic chromium (III) through oxidation reactions and the reduction of the toxic Cr(VI) to Cr(III).

In eukaryotes, metals can be transformed not only during accumulation and metabolism in the tissues but also during passage through the gastrointestinal tract. Little is known of the processes operating on metal contaminants during digestion and the need to clarify the effects of such transformations, physical and chemical, was emphasized. A considerable research effort has been expended on metal uptake and accumulation in eukaryotes. Much is known, mainly from laboratory studies, of the rates and the routes of accumulation. Less is known of the transformation of chemical species of metal contaminants within tissues and physiological fluids. Uptake and

accumulation of persistent organics directly or through the food chain has also been widely studied and the need for a better understanding of *in vivo* processes (by the identification and quantification of metabolites) is recognised as an important area of research activity.

Sequestration of contaminants by inclusion in lysosomes, by binding to metallothioneins and by deposition in mineral granules is a well known phenomenon in marine organisms. The contaminants are effectively rendered unavailable to other cellular components.

At the microbial level the meeting discussed how some bacteria are resistant to metal contaminants by envelope impermeability which excludes the contaminants from their interior. Other bacteria can accumulate contaminants but, possessing certain enzymes, can transform the contaminants. In this context, the group discussed not only contaminant toxicity but also contaminant mobility induced by both biomethylation and biohydridization yielding volatile hydrophobic metal toxicants.

Mercury is an example of a metal which, when methylated becomes more toxic. Arsenic, on the other hand becomes less toxic when methylated. Bacteria can oxidise As(III) to As(V). Bacterial transformation of tin species was also discussed. Monoalkyl tin species are adsorbed to particulate matter and rapidly sink through the water column. Dimethyl and trimethyl tin do not adsorb and thus can be shown to remain in the water column. Bacteria can also form several selenium species, including elemental selenium. Perhaps the most significant of these is dimethyl selenium oxide which is extremely volatile.

The meeting identified the adoption of a multidisciplinary approach, based on the use of data on the chemical structure, reactivity and partition properties and incorporating biological parameters in exposure and effects evaluation in future hazard and risk assessment studies.

7.2 Abiotic transformation of contaminants

When discussing abiotic transformation of contaminants the meeting recognised that metals are not present in water as simple ions but have extremely complex coordination chemistries. In freshwater, many metals exist as divalent cations ions coordinating four or six neutral H_2O groups. In seawater, a number of H_2O groups are replaced by chloride and hydroxyl ions with resultant changes in charge, molecular weight, size, hydrophobicity, volatility, etc. Thus at the freshwater-seawater interface some extremely complex reactions occur which, though we can often understand, we cannot always predict. Changes in metal bioavailability can accompany the transformation. Important abiotic transformations of organic contaminants (such as those occurring in DDT and dieldrin) require further study of processes such as photochemical reactions and the solubilization of contaminants by surface-active substances.

Our understanding of such reactions is derived from well-controlled laboratory experiments. In the environment, there is no such control and many competing reactions occur.

The chloride ion in seawater was described as an extremely efficient coordinator which can bind different metals, through molecular bridges, closer than they would exist even in alloys.

Association of metal contaminants with natural and man-made particles is dependent on the particle type and source. Some particles can be sources of metals e.g. volcanic ash and fluvial deposits from mineral-rich areas. Many particles contain bubbles or act as seeds for bubble-formation. Since the surface microlayers of bubbles and particles are prime sites of metal transformation, the meeting recognised that our understanding of processes operating at these sites need to be improved.

Another area where abiotic transformation is important is the oxic-anoxic interface in the water column and in the sediment column. Oxidation-reduction reactions occurring at this interface not only can they remove metals from solution but can also remobilise metals from particles. We are only beginning to recognise that anoxic conditions can build-up in the water column on small scales (temporal and spatial) and we need better methodology to detect the advent of such conditions and to predict their effects.

Many chemical equilibria result in the formation of a bioavailable species. If such a species is removed from the system e.g. through accumulation by biota, then the chemical equilibrium results in the formation of more of the bioavailable species with the result that non-bioavailable species eventually enter the food chain through simple chemical equilibrium considerations.

Unfortunately for those who wish to interpret nature, the above was recognised as a simplification since not only one but many of such reactions may occur simultaneously.

7.3 Strategy of environmental management/pollution control

One of the most important prerequisites for pollution control is to understand the system reliably. Simple laboratory approaches can help but cannot replace environmental measurements. It cannot be overstressed that natural systems are complex almost, if not altogether, beyond our current level of understanding.

Several approaches were identified by the meeting:

a) The most likely matrices and pathways should be identified for various contaminants so that the concept of "proper measurements, properly applied" can be implemented.

b) Quality assurance is a necessity. Participation in intercalibration exercises ensures that data is realistic and comparable to that of other investigators based upon reliable interchangeable reference or standard materials. An added advantage of intercalibration programmes is that defects in analytical methods can be identified and corrected for. It is recognized that sampling can contaminate transformation. Sampling techniques and analytical techniques should be optimised to minimise contamination, sampling variability and analytical variability. The development of direct and in-situ non-destructive measurements should be encouraged.

c) On the basis of the development of scientific knowledge on the fate and significance of contaminants in the environment the meeting recommended periodic review of existing legislation, and the update of accepted environmental quality criteria in line with scientific developments.

As marine environment pollution is not limited to national boundaries, an international approach to environmental management is required. The meeting recognised the importance of a preventative rather than curative approach in pollution control.

Since control measures often take several years to have an observable effect, it is essential to establish specimen banks so that realistic samples will be available many years later. Such a mechanism should ensure that temporal changes which are measured are real and are not due to changes in methodology and instrumentation. High levels of "noise" in relating ecological and toxicological data was cited as a particular problem in relation to developing an interdisciplinary approach to environmental pollution strategy. There is a fundamental need for the collation of good data on ecologica systems if extrapolation to include contaminant effects are to be realistic.

A final point relating to biotic transformation of contaminants in relation to pollution management was the potential use of biota to clean up contaminated environments. For example, cyanobacteria are being used to remove metals from industrial effluents just as oil-degrading bacteria are used for oil spill clean-up.

It was recognised that future progress would best be achieved through interdisciplinary research efforts. One of the lessons learned during the meeting was that exchange of ideas between scientists with different backgrounds and expertise can be a very fruitful process not only in improving sampling and analytical techniques but also in interpreting data. Artificial imposition of "chemical" or "biological" or "geological" strategies and philosophies on an heterogeneous natural environment is effective up to a point but the meeting felt that this point has now been surpassed. Co-ordinated research efforts, with a sharing of knowledge, facilities and equipment, was felt by the meeting to be the optimal strategy for future developments.

8. FUTURE RESEARCH NEEDS (Agenda item 8)

The most important strategy for future research was felt to be an interdisciplinary approach. However several specific areas were identified where such an approach should be focussed.

(a) Better characterization of particulate matter, both man-made and natural, is required. This should include both qualitative and quantitative aspects.

(b) Development of new direct and non-destructive analytical methodologies and improvement of existing ones are needed to identify different chemical species in the natural environment and in the tissues of marine organisms.

(c) Sampling techniques should be improved and standardised at several levels.

(i) to minimise, since it is impossible to eliminate, variability,
(ii) to obtain samples which are suitable for bioassay work,
(iii) to facilitate spatial and temporal comparisons.

Efforts should be made to obtain representative samples.

(d) Study of the behaviour of contaminants at cellular and subcellular levels. Elucidation of mechanisms of toxicity is important not only to determine but also to devise appropriate bioassays to measure contaminant effects.

(e) Study of the degradation of organic contaminants especially those whose metabolites are expected to accumulate to a higher extent and be more toxic than the parent compound.

(f) Ecotoxicological studies should focus on areas such as synergistic contaminant effects.

(g) More attention should be paid to the role of organic material associated with the particulate phase and especially in relation to variations in carbon particle size and distribution relationships.

(h) The role of micro-organisms in metal transformation is slowly being given the recognition it deserves. More attention should be focussed on prokaryote interactions with metal contaminants and on factors modulating their transformation.

(i) A better understanding of natural processes operating in uncontaminated environments would greatly aid the interpretation of data from contaminated environments. Even though contaminated environments receive more attention, uncontaminated ones should not be ignored.

(j) Information on processes operating at the air-sea interface is still limited. Considering the quantities of contaminants entering the marine environment from the atmosphere and the extremely high concentrations of contaminants in the upper 200 micrometres of the water column, our understanding of this microlayer should be enhanced.

(k) More attention should be given to designing laboratory experiments by taking into consideration the parameters existing in the natural evnironment so that a more realistic simulation of the natural conditions is achieved. Additional work employing mesocosm or even microcosm experiments in the field itself is needed.

(l) Our understanding of the meaning of high contaminant levels in various matrices and their relation to measured effects should be improved. The interpretation of data in the context of environmental impact needs to be improved at population, organism, cellular and sub-cellular level.

(m) As a corollary to (l) above, the meeting felt that too much attention was being paid to making measurements and not enough attention was paid to the interpretation of results in terms of environmental risk.

(n) A better understanding of the environmental behaviour of contaminants and especially of the mechanisms involved in their distribution and fate is necessary for the prediction of the environmental target.

9. RECOMMENDATIONS (Agenda item 9)

The meeting made the following recommendations:

a) Interdisciplinary research should be strongly encouraged in environmental studies. Expertise in biochemistry, geology and physical oceanography were quoted as examples to be included in such research programmes.

b) Increased communication and collaboration between scientists should be encouraged especially between advanced and less advanced laboratories in developing countries. The provision of equipment alone is not considered satisfactory and joint programmes should also be initiated and promoted. The organization of international meetings was considered a good way of getting appropriate scientists together.

c) Bioassay techniques should be developed to aid the interpretation of contaminant effects.

d) Sampling techniques need to be improved and to be standardised- particularly where bioassays need to be performed on the samples.

e) A wider use of statistical techniques should be encouraged in the interpretation of the data.

f) Participation in international intercomparison exercises should be mandatory for all scientists involved in the collection and provision of data on contaminant levels especially based on interlaboratory comparisons defined by mutual standard reference materials.

g) A specimen bank should be established which can store, for decades if necessary, realistic environmental samples, for the use of programme participants.

10. ANY OTHER MATTER (Agenda item 10)

The publication of the proceedings was brought up under this agenda item. The Technical Secretary explained that the report of the meeting will be published very soon as a preliminary document. The papers presented will be published in full either in the FAO Fisheries Reports Series or the MAP Technical Reports Series. Participants were encouraged to also publish their papers in international scientific journals.

It was agreed that the papers should be reviewed by other participants of the meeting. People wishing to submit a revised version of their paper before this review, should do so as soon as possible but not later than the end of October 1990.

11. ADOPTION OF THE REPORT (Agenda item 11)

The present report was adopted by the meeting on Friday, 28 September 1990.

12. CLOSURE OF THE MEETING (Agenda item 12)

In his closing remarks, the Technical Secretary expressed satisfaction for the results of the meeting and the constructive spirit in which it was conducted. He also thanked the participants, the Officers of the meeting, the guest-speaker and everybody else who contributed directly or indirectly in the success of the meeting. Special thanks were expressed to ENEA for the excellent hospitality.

An exchange of courtesies followed after which the Chairperson closed the meeting.

ANNEX I

LIST OF PARTICIPANTS

Fouad ABOSAMRA
High Institute of Applied Sciences
and Technology
Environmental Studies Laboratory
P.O. Box 4470
Damascus
SYRIA

Tel.: 963-11-770547/8/9
Telex: 411374
Fax: 963-11-223771

Franco BALDI
Dipartimento di Biologia Ambientale
University of Siena
Via P.A. Mattioli, 4
53100 Siena
ITALY

Tel.: 39-577-298864
Telex: 572459 UNIV SI I
Fax: 39-577-298860

Corrado BARGHIGIANI
Institute of Biophysics
Italian National Research Council
Via S. Lorenzo 26
56100 Pisa
ITALY

Tel.: 39-50-513251
Fax: 39-50-553501

Josep M. BAYONA
Centro de Investigación y
Desarrollo C.S.I.C.
Departamento de Quimica Ambiental
Jorge Girona Salgado 18-26
08034 Barcelona
SPAIN

Tel.: 34-3-2040600
Telex: 97977
Fax: 34-3-2045904

Michael BERNHARD
Energia Nucleare Energie
Alternative (ENEA)
Casella Postale 316
19100 La Spezia
ITALY

Tel.: 39-187-530249
Telex: 282861 ENEAST I
Fax: 39-187-536213

Frederick E. BRINCKMAN
Polymers Division
United States Department of Commerce
National Institute of Standards
and Technology
(formerly National Bureau of Standards)
Gaithersburg
Maryland 20899
U.S.A.

Tel.: 1-301-9755737
Telex: 197674 NIST-UT
Fax: 1-301-9752128

Renzo CAPELLI
Istituto di Analisi e Tecnologie
Farmaceutiche ed Alimentari
Universita di Genova
Via Brigata Salerno (Ponte)
16147 Genova
ITALY

Tel.: 39-10-3532604
Fax: 39-10-3532684

Vassiliki-Angélique CATSIKI
Department of Biological Oceanography
National Centre for Marine Research
Aghios Kosmas
Hellinikon
166 04 Athens
GREECE

Tel.: 30-1-9829237
Telex: 224135 NCMR GR
Fax: 30-1-9833095

Colette CHASSARD-BOUCHAUD
Biologie et Physiologie des organismes marins
Université Pierre et Marie Curie
4, Place Jussieu
Bâtiment A, 4ème étage
F-75252 Paris, Cedex 05
FRANCE

Tel.: 33-1-44273155
Telex: 200145F UPMCSIX F
Fax: 33-1-44273866
Telemail: 933-1-44273833

Salvatore CHIAVARINI
Department of Environmental Protection
ENEA
Via Anguillarese 301
00060 S. Maria di Galeria
Rome
ITALY

Tel.: 39-6-30481
Telex: 613296 ENEACA I
Fax: 39-6-30483594

Bozena COSOVIC
"Rudjer Boskovic" Institute
Centre for Marine Research
Bijenicka 54
41000 Zagreb
YUGOSLAVIA

Tel.: 38-41-425457
Telex: 21383 YU IRBZG
Fax: 38-41-425497

Ezzeddine FEDHILA
Tunisian Navy
Ministry of Defense
Naval Base
Bizerta
TUNISIA

Tel.: 216-2-31700

Romano FERRARA
Istituto di Biofisica
Consiglio Nazionale delle Ricerche
Via S. Lorenzo 26
56100 Pisa
ITALY

Tel.: 39-50-513111
Fax: 39-50-553501

Marco FILIPPELLI
Laboratorio Chimico d'Igiene
Via Fontevivo 129
19100 La Spezia
ITALY

Tel.: 39-187-512049
Fax: 39-187-533592

Valentino U. FOSSATO
Istituto di Biologia del
Mare del CNR
Riva 7 Martiri 1364/A
30122 Venice
ITALY

Tel.: 39-41-5207622
Fax: 39-41-5204126

Carlo GAGGI
Department of Environmental Biology
University of Siena
Via delle Cerchia 3
53100 Siena
ITALY

Tel.: 39-577-298836
Telex: 572459 UNIV SI I
Fax: 39-577-298860

Philippe GARRIGUES
Laboratoire de Photophysique
et Photochimie Moléculaire
Université de Bordeaux I
351, Cours de la Libération
33405 Talence Cedex
FRANCE

Tel.: 33-56846305
Telex: 560706
Fax: 33-56846645

James LAMOND
Department of Environmental
Chemistry
University of Crete
P.O. Box 1470
Iraklio 71110
Crete
GREECE

Tel.: 30-81-235015 ext. 21
Telex: 262728 MPUC
Fax: 30-81-233669

Biancaelena MASERTI
Istituto di Biofisica
Consiglio Nazionale delle Ricerche
Via S. Lorenzo 26
56100 Pisa
ITALY

Tel.: 39-50-513252, 513111
Fax: 39-50-553501

Nicolas MIMICOS
National Research Centre for
Physical Sciences "Democritos"
Aghia Paraskevi
Athens 153 10
GREECE

Tel.: 30-1-6513111 ext. 333
Telex: 216199

Vincenzo MINGANTI
Istituto di Analisi e Tecnologie
Farmaceutiche ed Alimentari
Università di Genova
Via Brigata Salerno (Ponte)
16147 Genova
ITALY

Tel.: 39-10-3532605
Telex: 271114 UNIVGE I
Fax: 39-10-3532684

Anastasia MYLONA
Laboratory of Chemical Oceanography
National Centre for Marine Research
Aghios Kosmas
Hellinikon
166 04 Athens
GREECE

Tel.: 30-1-9821300
Telex: 224135 NCMR GR
Fax: 30-1-9833095

Radovan PLANINC
Marine Biological Station
66330 Piran
JLA 65
YUGOSLAVIA

Tel.: 38-66-73740
Fax: 38-66-74432

Chaim RAV-ACHA
School of Applied Science and Technology
Division of Environmental Science
and Technology
The Hebrew University of Jerusalem
Girat-Ram Campus
91904 Jerusalem
ISRAEL

Tel.: 972-2-421290
Fax: 972-2-666804

Michèle ROMEO
INSERM
Unité 303 "Mer et Santé"
B.P. 3 - La Darse
06230 Villefranche-sur-mer
FRANCE

Tel.: 33-93763875
Fax: 33-93763877

Abdraouf SANCHOU
Tunisian Navy
Ministry of Defense
Tunis
TUNISIA

Tel.: 216-1-276300

Michael SCOULLOS
Department of Chemistry
Division III/Environmental and
Marine Chemistry
University of Athens
Panepistimioupolis, Kouponia
157 01 Athens
GREECE

Tel.: 30-1-7219926/3605319
Fax: 30-1-3622535

Suleyman TUGRUL
MEIU - Middle East Technical University
Institute of Marine Sciences
P.K. 28 Erdemli
Içel 33731
TURKEY

Tel.: 90-7586-1406
Telex: 67796 DMSTR

Ilija VUKADIN
Institute of Oceanography and Fisheries
P.O. Box 114
Mose Pijade 63
58001 Split
YUGOSLAVIA

Tel.: 38-58-46688
Fax: 38-58-46593

Tomislav ZVONARIC
Institute of Oceanography and Fisheries
P.O. Box 114
Mose Pijade 63
58001 Split
YUGOSLAVIA

Tel.: 38-58-46688
Fax: 38-58-46593

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

Gabriel P. GABRIELIDES
Technical Secretary of the Meeting
Senior Fishery Officer (Marine Pollution)
Food and Agriculture Organization of the
United Nations
Co-ordinating Unit for the Mediterranean
Action Plan
P.O. Box 18019
Vas. Konstantinou 48
GR 116 10 Athens
GREECE

Tel.: 30-1-7244536
Telex: 222611 MEDU GR
Fax: 30-1-7218246

Vanta PAPAPANAGIOTOU
FAO Secretary
Co-ordinating Unit for the Mediterranean
Action Plan
P.O. Box 18019
Vas. Konstantinou 48
GR 116 10 Athens
GREECE

Tel.: 30-1-7244536
Telex: 222611 MEDU GR
Fax: 30-1-7218246

INTERNATIONAL ATOMIC
ENERGY AGENCY

Canice NOLAN
International Laboratory of Marine
Radioactivity
International Atomic Energy Agency
19, Avenue des Castellans
98000 MONACO

Tel.: 33-93-504488
Telex: 479378 ILMR
Fax: 33-93-257346

ANNEX II

AGENDA OF THE MEETING

1. Opening of the meeting
2. Background and scope
3. Election of officers
4. Adoption of the agenda
5. Organization of the work
6. Presentation of papers
7. The role of transformation and bioaccumulation of chemical contaminants in the marine environment vis-a-vis pollution control
8. Future research needs
9. Recommendations
10. Any other matter
11. Adoption of the report
12. Closure of the meeting

ANNEX III

LIST OF PAPERS PRESENTED

Key-note paper

1. Realistic appraisal of combined chemical and biotic transformations of land-sea contaminants by on-site molecular and element-specific measures assuring environmental controls: current status, trends and prospects, by **F.E. BRINCKMAN**

Other papers

2. Bioaccumulation of PAHs in selected biota from Syrian coastal waters, by **F. ABOSAMRA, R. NAHHAS, S. BABA and G. TALJO**

3. Microbial transformation of mercury, by **F. BALDI**

4. Mercury-selenium and cadmium-selenium relations in edible species of the northern Tyrrhenian Sea, by **C. BARGHIGIANI, A. D'ULIVO, L. LAMPUGNANI, D. PELLEGRINI, S. DE RANIERI and R. ZAMBONI**

5. Partitioning of organic microcontaminants between coastal marine compartments, by **J.M. BAYONA, M. VALLS, P. FERNANDEZ, C. PORTE, I. TOLOSA, and J. ALBAIGES**

6. Biotic and abiotic transformation of inorganic mercury into methylmercury, a critical review, by **M. BERNHARD and M. FILIPPELLI**

7. The impact of size on the bioaccumulation rate of heavy metals and PAH's by Mytilus galloprovincialis from Saronikos Gulf, by **V.A. CATSIKI, A. MYLONA and N. MIMICOS**

8. Fate and availability of trace metal pollutants in the mussel Mytilus sp. Uptake and distribution at the cellular and subcellular levels, by **C. CHASSARD-BOUCHAUD, F. KLEINBAUER, F. ESCAIG and P. BOUMATI**

9. Distribution and fate of TBT and its degradation products in the La Spezia Gulf, by **S. CHIAVARINI, C. CREMISINI and R. MORABITO**

10. Surface active substances and processes at natural phase boundaries, by **B. COSOVIC**

11. Polychlorinated biphenyls in water, suspended particulate matter and zooplankton from the open Adriatic Sea, by **V.U. FOSSATO, L. CRABOLEDDA and F. DOLCI**

12. Distribution and biotransformation of aromatic compounds in coastal Mediterranean ecosystems, by **Ph. GARRIGUES, C. RAOUX, J.F. NARBONNE, D. RIBERA, P. LEMAIRE, A. MATHIEU, J.P. SALAUN and M. LAFAURIE**

13. Distribution, accumulation and transformation of organic contaminants in an Eastern Mediterranean coastal area, by **J.D.G. LAMOND and E.G. STEPHANOU**

14. Posidonia oceanica: uptake and mobilization of mercury in the Mediterranean basin, by **B. MASERTI, R. FERRARA and M. MORELLI**

15. The bioaccumulation of heavy metals and petroleum hydrocarbons in mussels from polluted and unpolluted areas of Saronikos Gulf, by **N. MIMICOS, A. MYLONA and V.A. CATSIKI**

16. Trace metal accumulation in Molluscs: The effects of variables and variability on sampling considerations, by **C. NOLAN**

17. Formation of organochlorine compounds during chlorination of seawater in power plant cooling systems: A mutagenic assessment, by **CH. RAV-ACHA, H. SHUVAL and E. AVISAR**

18. Methylmercury in deep-sea organisms from the Mediterranean, by **A. RENZONI, G. CHEMELLO, C. GAGGI, R. BARGAGLI and E. BACCI**

19. The importance of gelatinous plankton organisms in the storage and transfer of trace metals in the north-western Mediterranean, by **M. ROMEO, M. GNASSIA-BARELLI and C. CARRE**

20. Microcosm experiments on the accumulation and release of trace metals (Zn, Cu, Cd) by the macroalgae Ulva lactuca, by **M.J. SCOULLOS and H. CABERI**

21. Occurrence and fate of methyltin species in the aquatic environment, by **S. TUGRUL, N. KUBILAY, S. YEMENICIOGLU, I. SALIHOGLU and C. SAYDAM**

22. Fate and distribution of chromium in waters, sediments and organisms of the Kastela Bay, by **I. VUKADIN and N. ODZAK**

23. The cycling of mercury through the marine environment of Kastela Bay, by **T. ZVONARIC**