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Impact of oil and related chemicals and wastes on the marine environment

IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP
Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP)

GESAMP Reports and Studies No. 50

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Impact of oil and related chemicals on the marine environment

IMO
London, 1993

Printed by the International Maritime Organization
4 Albert Embankment, London SE1 7SR

Notes

1 GESAMP is an advisory body consisting of specialized experts nominated by the Sponsoring Agencies (IMO, FAO, UNESCO, WMO, WHO, IAEA, UN, UNEP). Its principal task is to provide scientific advice on marine pollution problems to the Sponsoring Agencies and to the Intergovernmental Oceanographic Commission (IOC).

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For bibliographic purposes, this document may be cited as:

GESAMP (IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution) 1993: Impact of Oil and Related Chemicals and Wastes on the Marine Environment. *Rep. Stud. GESAMP* (50): 180pp.

86# 7-1-5-36

Definition of marine pollution by GESAMP:

Pollution means the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater and reduction of amenities.

Members of the GESAMP Working Group on the Impact of Oil, Individual Hydrocarbons, and Related Chemicals on the Marine Environment, Including Used Lubricating Oils, Oil Spill Control Agents, and Wastes from Offshore Petroleum Operations

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Acknowledgements

1 The employers and sponsors of all members of the Working Group are greatly thanked for their support of this project. Environment Canada and Dalhousie University kindly supported P.G. Wells during final editing in 1992.

2 Dr. Patricia Lane of Halifax, Nova Scotia, is thanked for her early draft of section 2.6, conducted in 1990 under contract to the International Register for Potentially Toxic Chemicals, United Nations Environment Programme, Geneva.

3 Members of GESAMP and all of the technical reviewers are thanked for their comments and contributions.

4 Special thanks are extended to Ms. Jennie Hallett of the International Maritime Organization for her dedicated commitment to the preparation of the final manuscript and her long support to the Working Group throughout its work and its meetings.

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Part III – Bibliography

Foreword

In 1977 GESAMP published its study *Impact of Oil on the Marine Environment* (Rep. Stud. GESAMP (6)). Since that time there have been many advances in the fields of marine pollution research and combating pollution respectively. The International Maritime Organization (IMO) therefore requested GESAMP to prepare a new synopsis of current knowledge on oil pollution supplementing the previous GESAMP review. IMO and the other sponsoring agencies of GESAMP agreed that, besides oil and individual hydrocarbons, this study should include dispersants and other control agents in oil spill responses as well as wastes from offshore petroleum operations.

In order to achieve this objective, GESAMP, at its nineteenth session in 1989, established a sub-group to its Working Group on the Review of Potentially Harmful Substances, asking it to operate under the terms of reference of the Working Group as follows:

1 to prepare short referenced reviews on selected substances which include an assessment of the following factors:

   (a) the total of particular substances which reach the marine environment (on a local, regional and global scale) with particular attention being given to the relative importance of land-based sources;

   (b) the fate (transfer, distribution and transformation) of these substances in the marine environment;

   (c) the effects of these substances on the marine environment and adjacent coastal areas, both direct and indirect, on living resources and human health; and

2 to produce a scientific evaluation of the harmful effect of substances released into the marine environment on living resources, human health, aesthetics and other legitimate uses of the marine environment and adjacent coastal areas.

The Group was jointly sponsored by IMO, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Environment Programme (UNEP).

The Group first met in March 1990 under the chairmanship of Dr. P.G. Wells and subsequently twice before presenting its final report to the twenty-second session of GESAMP in March 1992, which adopted the report for publication in the GESAMP Reports and Studies series.

Part I - Executive Summary

Scope and intent of the review

GESAMP, at its nineteenth session (April 1989), agreed that a group would be established to prepare a summary review which would update the previous GESAMP (1977) review *Impact of Oil on the Marine Environment*. It would cover oil and individual hydrocarbons, used lubricating oils, chemical control agents for oil spills, and wastes from offshore petroleum operations. It would consider all major knowledge generated since the mid-1970s, primarily through the use of existing syntheses on the topic; the presentation was to be concise, and to include recommendations for further work.

The Working Group covers their topics comprehensively, from a consideration of the composition, sources and inputs of oil to its ecological and human health effects and its effects on man's use of the sea. The review addresses several key questions on the present levels of contamination, the impact of hydrocarbons and related chemicals on marine biota, the recovery potential of marine ecosystems exposed to these contaminants, the degree of protection required for marine ecosystems known to be vulnerable and sensitive, and recommended research and other actions to fill gaps in knowledge.

The review describes the hazards of marine oil pollution and associated chemicals and wastes as they are understood currently, and clarifies the importance of reducing oil inputs in coastal and offshore waters. It assists in considering fundamental questions, asked by the public and decision-makers alike, such as: how much oil is entering our oceans, and how much harm is it doing?

Summary, conclusions, and recommendations

1 Oil and individual hydrocarbons

1.1 Summary

1.1.1 The input of oil from anthropogenic sources into the marine environment has decreased during the past decade. This is largely due to measures required by international conventions on the prevention of marine pollution by oil from shipping. Although the spatial density of sampling and duration of time series are different in various parts of the world, there are indications that reduction of oil contamination has occurred on a global scale. Estimates in 1981 showed that 3.2 million tonnes of oil per year enter marine environments from all sources; the estimate for 1990 is 2.35 million tonnes. Annual amounts can vary greatly, depending upon accidents and acts of war. There is increasing evidence that the input of oil from land-based sources has so far been underestimated; enclosed and semi-enclosed coastal areas receive far higher amounts than have been indicated in global estimates.

1.1.2 The fate of oil in the marine environment has been studied extensively in both qualitative and quantitative detail over the past 15 years. The ecological impacts of oil are also better understood – many biological effects have been measured and some toxicological patterns have become apparent. Marine birds and mammals are visible victims of oil spills, and concern for chronic sublethal effects caused by spills in low-energy, shallow coastal waters and shorelines is increasing. Some habitats, such as exposed rocky shorelines, recover quickly from oiling events. Other ecosystems, such as mangroves, salt marshes, seagrasses and coral reefs, and polar habitats, are particularly vulnerable and sensitive to oil spills, and may take years to recover.

1.1.3 Oil can affect man's use of the sea. Spills have low or negligible impacts on fish populations but can taint fish and invertebrates, although there is little or no evidence of tainting of fish and shellfish, even by such events. In addition, tar can coat shorelines and harbours, and boats and fishing gear may be oiled during spills. The impacts of spills, large or small, are clearly better understood now than in the mid-1970s and, although there are major efforts worldwide to improve response capabilities, it is generally acknowledged that prevention is the best way of reducing the known impacts of oil on the marine environment and its resources.

1.2 Conclusions

1.2.1 The best current estimate is that 2.35 million tonnes of oil per year enter the marine environment from all sources. This estimate is highly influenced by number and size of shipping spills each year. At least 15% comes from natural oil seeps. Anthropogenic sources include chronic discharges from storage facilities and refineries, discharges from tankers and other shipping along major routes, and accidental events such as oil spills and ruptures of pipelines.

Sources also include river-borne discharges, diffuse discharges from industrialized municipal areas, offshore oil production, and the atmosphere. The sources vary in importance geographically but the primary inputs are generally from land-based sources (refineries, municipal wastes, urban run-off). Recent wars have resulted in major inputs (i.e. Arabian/Persian Gulf). Although oil spills and tar on beaches are highly visible, inputs of oil from land-based sources are of increasing concern, especially near urban centres.

1.2.2 Due to measures required by international conventions on prevention of oil pollution, the input of oil into the marine environment from maritime operations has decreased during the past three decades. In this regard, the entry into force of MARPOL 73/78, Annex I, in 1983 has had a substantial positive impact in decreasing the amount of oil that enters the sea from transportation activities, inputs decreasing from 1.47 million tonnes in 1981 to 0.54 million tonnes in 1989 (IMO, 1990). However, the input has varied by more than a factor of 10 from year to year, with 1979 (IXTOC blowout), 1983 to 1988 (Iran–Iraq war), and 1991 (the Gulf conflict) showing extra inputs which were many times the average of intervening years. Total floating tar observed in 1985 in shipping lanes and their associated surface currents was one-fourth or less of that observed in 1971–72, based on measurements in the Sargasso and Mediterranean Seas. Tanker accidents contribute to 5% of oil input, based on 1990 estimates, but volumes spilled annually are highly variable, making the identification of trends difficult. Tar continues to impair amenity beaches and coastlines in many parts of the world.

1.2.3 Physical, chemical and biological fates of hydrocarbons from spilled oils are better understood now in qualitative and quantitative terms. Many new methods of analysis for hydrocarbons in seawater, sediments and biological tissues have been developed. Investigations have addressed transformation (photo-oxidation, metabolic) by-products of specific hydrocarbons, and other basic characteristics of oils in the environment are better understood. Recent research on the polar fractions of dissolved oil residues has shown the presence of large numbers of oxygenated derivatives of aromatic hydrocarbons; their concentrations often exceed those of each parent hydrocarbon and their toxic effects to marine organisms are largely unknown. Quantitative modelling is most advanced in the areas of transport of slicks, evaporative weathering of slicks and uptake of components of slicks in selected species. Many new biochemical, physiological and toxicological techniques have been developed and applied in research and monitoring.

1.2.4 Reproductive, developmental and behavioural processes are very sensitive to exposure to hydrocarbons. Generally, young life stages are more sensitive than adults, and many juvenile and adult crustaceans and echinoderms are more sensitive than juvenile and adult fish. It is well established that different oil types vary in their toxicities, and that acute toxicity is largely due to components of the water-soluble fractions and dependent upon exact conditions and duration of exposure to them. Chronic sublethal effects caused by petroleum hydrocarbons spilled or discharged in low-energy, shallow coastal waters remain a valid concern.

1.2.5 Marine wildlife (turtles, seabirds, mammals) are often the most conspicuous victims of oil spills. Diving and surface-dwelling populations of seabirds, and sea otters and polar bears in particular, are now known to be vulnerable and sensitive to oiling. Documentation from the field on the effects of oiling on other mammals, especially cetaceans, is scarce.

1.2.6 Short-term impacts of spills are well understood. Except for wildlife, biological concerns largely centre on shallow near-shore areas and coastlines. There is some evidence that petroleum causes long-term effects on populations and communities at spill sites. Some habitats (e.g. low-energy marshes and mangroves) can require decades to return to their pre-spill condition of population, species diversity and habitat quality, while others recover relatively quickly (months to one or two years). Such recovery depends upon degree of oiling, oceanographic regime, and type of habitat and species affected.

1.2.7 Oil spills have low or negligible impacts on fish populations. Significant impacts on local populations generally occur only in shallow waters with poor circulation. In such locations, only small proportions of total regional populations are usually affected.

1.2.8 Tropical coastal ecosystems, such as mangroves and coral reefs, as well as seagrasses in all locations are particularly vulnerable and sensitive, due to greater retention of oil and the exposure of many species and life stages year-round. Damaged coastlines may prematurely erode and important habitats may be lost. Little is known about the time-scales and the recovery patterns and processes of such ecosystems after acute or chronic oiling.

1.2.9 Although large and small spills often result in closure of fisheries by regulatory authorities, there is little or no evidence of tainting of fish or shellfish, even by major spills.

1.3 Recommendations

1.3.1 Controls of discharges of oil from sources other than shipping (e.g. land-based sources, offshore activities) should be strengthened, where necessary, within appropriate national and international systems. More information is required on the characterization of land-based inputs of oils and should be systematically collected by national governments.

1.3.2 More efforts should be made by the appropriate international industrial and intergovernmental bodies in assisting governments in effectively implementing existing oil-pollution conventions.

1.3.3 To diminish the impacts of oil spills, governments should be urged to ratify the recently adopted International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990, which requires the establishment of oil pollution emergency plans on ships and offshore installations and at ports and oil handling facilities, together with national and regional contingency plans, as appropriate.

1.3.4 Global and regional monitoring programmes need to be continued in all marine environments to describe concentrations and distributions of hydrocarbons at the sea surface, and in coastal sediments and biota, and to verify trends.

1.3.5 A selection of important and representative areas worldwide where spills are most likely to occur should be the focus of appropriate pre-spill research and monitoring studies. Studies at experimental spill sites and spills of opportunity should be encouraged, for both science and testing of response equipment and methods.

1.3.6 Research is needed on the fate and effects of phototransformation by-products of oils and the nitrogen-, oxygen- and sulphur-substituted polycyclic aromatic hydrocarbons (PAHs) found in crude oils. If results indicate reasons for concern, methods should be developed for monitoring purposes.

1.3.7 *Intertidal and sublittoral communities are at most risk from oil spills and there is limited information on their recovery rates. Sub-acute toxicity studies are required to define dose-response relationships for selected benthic organisms exposed to representative oils.*

2 Used lubricating oils

2.1 Summary

2.1.1 Crankcase oils are an important source of PAHs and lead, as well as trace levels of other contaminants such as chlorinated dibenzodioxins, in the marine environment. Sediments contaminated with high levels of crankcase oils, having PAH concentrations in the range 3 to 5 μg/g, are expected to be toxic to selected marine species associated with sediment. The risk of either chemical contamination or the tainting of seafood by crankcase oil is expected to be low or negligible. Any environmental and human health concerns should be focussed on urbanized and industrial harbours. Bilge waters containing used crankcase oil and other lubricating oils are responsible for many bird kills in coastal waters and may be important contributors of beach tar in some regions. Except for possible point sources of contamination, it is expected that industrial oils other than used lubricating oils are of minor environmental importance.

2.2 Conclusions

2.2.1 Crankcase oils are important contributors to point sources of combustion-generated PAHs and lead, as well as trace levels of other contaminants such as chlorinated dibenzodioxins.

2.2.2 Acute toxic effects of crankcase oils in the marine environment are expected to be negligible. However, sediments contaminated with high levels of crankcase oils are expected to be chronically toxic to some marine species, especially those associated with sediment.

2.2.3 There is some evidence that combustion-generated sources of PAHs in sediment in the range 3 to 5 μg/g can produce adverse effects, including carcinogenesis, in some species. This range represents approximately 10 times the background concentration of PAHs.

2.2.4 The risk of either chemical contamination or the tainting of seafood by crankcase oils is expected to be low or negligible.

2.2.5 Any environmental and human health concerns about used lubricating oils and industrial oils should be focussed on urbanized and industrial harbours.

2.3 Recommendations

2.3.1 More information is needed on production volumes and quantities of industrial oils (hydraulic, rolling, cutting, etc.) entering the marine environment and on the sub-acute toxicity of selected additives.

2.3.2 More information is needed on the role of bilge (engine waste) discharges, as distinct from tanker ballast discharges, in the formation of persistent residues such as beach tar.