Scientific and Technical Advisory Panel to the Global Environment Facility:

the use of bioindicators, biomarkers and analytical methods for the analysis of POPs in developing countries

(Preface and Executive Summary only. The full report will be posted on STAP's website shortly at www.unep.org/stapgef)

May 2004

PREFACE

In many developing countries Persistent Organic Pollutants (POPs) are still used for agricultural and disease vector control, as well as for industrial purposes. In these countries the stockpiles of obsolete POPs create significant problems that are compounded by municipal-waste burning on open sites. When this waste is burned at low temperatures, it produces significant quantities of polychlorinated dioxins and related chemicals. Recent surveys, conducted in a number of Asian countries, indicate that such activities lead to local, regional and widespread global contamination. Studies show that alarming levels of POPs are present in the environment as well as in human beings. Dealing with these problems is a large and complex task: it requires suitable monitoring and analytical methods. However, data about the use, contamination and effects of POPs are often lacking, impeding the introduction of appropriate measures to deal with the problem.

Many of the existing methods for the measurement of POPs, in particular dioxins and furans, are highly technical and relatively expensive, involving sophisticated instruments and special chemicals. Because laboratories in developing countries often do not have the required equipment, they often find it difficult to detect and measure these chemicals in their environment. The high cost of analysis is another significant barrier to routine monitoring. Moreover, because many of the pollutants are present in ultra-low levels in the environmental samples, large number of samples must often be collected, particularly from the marine environment. This means that the pollutants are also difficult to quantify. It is therefore imperative to develop and test simple, inexpensive and accurate methods for scientific monitoring and assessment. Such methods could be based on the use of biomarkers and bioindicators[1] and be combined with analytical procedures that can be routinely performed at reasonable cost. One possible approach for routine measurements would be to deploy biomarker and bioindicator methods and combine these with low-cost analytical methods to establish the extent of contamination. Only if contamination is

[1] In very broad terms, a bioindicator measures the concentration of contaminants in an organism and a biomarker measures the effect these contaminants have on the organism, e.g. a change in fertility.

detected would contaminants then be sampled and analysed by methods that are capital-intensive and require high-tech equipment.

The Stockholm Convention and Basel Convention signaled that there is an international commitment to the identification and management of POP wastes. The Global Environment Facility (GEF) has been designated, on an interim basis, as the financial mechanism of the Stockholm Convention. In response to this, the GEF prepared a draft of an Operational Programme for '*Reducing and Eliminating Releases of POPs into the Environment'* as a framework for its interventions. At its Second Assembly, held in Beijing in October 2002, the GEF formally approved POPs as a new focal area.

The objective of the Operational Programme is to assist eligible countries in reducing and eliminating releases of POPs into the environment — thereby contributing to the implementation of the Stockholm Convention and to the protection of human health and the global environment. The Operational Programme identifies the potential of targeted research projects for development and promotion of rapid assessment methodologies, including biological markers for environmental and human monitoring, as data gaps that currently hinder sound management decisions and for raising awareness of the POPs issue.

The GEF therefore asked the Scientific and Technical Advisory Panel (STAP) for a review of cost-effective and accurate methods available for determining the presence and levels of POPs in the environment in developing countries with special emphasis on the use of bioindicators and biomarkers.

STAP convened a workshop in Tsukuba City, Japan, (10–12 December 2003) which examined the applicability and efficacy of different bioindicators and biomarkers for the analysis and assessment of POPs in developing countries, and of cost-effective analytical techniques in environmental monitoring and surveillance. The workshop was co-hosted by the Government of Japan.

The workshop brought together a cross-section of experts from developed and developing countries and was attended by STAP-member Professor Shinsuke Tanabe (Professor of Environmental Chemistry and Toxicology at the Centre for Marine Environmental Studies, Ehine University, Japan), representatives from the GEF Secretariat, the GEF

Implementing Agencies (UNDP, UNEP, World Bank), as well as representatives from UNIDO and FAO, and the STAP Secretariat.

STAP commissioned three technical reviews: on biomarkers, bioindicators, and the use of analytical methods in environmental monitoring and surveillance. The reviews form the backbone of STAP's advice. These documents are by necessity technical but with the entry into force of the Stockholm Convention on 17 May 2004, I hope they will assist the GEF in deciding how to support activities for monitoring POPs in developing countries.

Julia Carabias
STAP Chair

30 April 2004
Washington, DC

Executive Summary

1. STAP was asked by the Global Environment Facility (GEF) to provide advice on the use of biomarkers and bioindicators for monitoring and measuring persistent organic pollutants (POPs), to supplement more traditional chemical analysis. STAP therefore commissioned three technical reviews: on bioindicators, biomarkers and the use of chemical analytical methods[2] in environmental monitoring and surveillance. These papers (annexed to this report) were discussed and reviewed at a technical workshop, co-hosted by the Government of Japan, in Tsukuba City, 10–12 December 2003.
2. Persistent organic pollutant residues in soils, sediments, water and living organisms pose and will continue to pose a risk for wildlife and humans. At present, many of the analytical techniques to detect the presence of POPs are expensive and cannot be easily implemented in developing countries. Thus, the review papers attempted to summarize the methods used in developed countries, that are cost-effective, with special emphasis on bioindicators and biomarkers, highlighting those which can be rapidly implemented in developing countries.
3. Bioindicators are defined as the animal(s) or plant(s), which accumulate POPs in their tissues and organs in direct relation to the presence of POPs in their surroundings. Thus, the concentration of POPs in tissues and organs of indicator organisms (e.g. fish, crustaceans, bivalves, aquatic and terrestrial mammals, birds, humans) can be used to indirectly estimate the concentration of POPs in the surrounding environment. Bioindicator programmes can therefore be designed to reveal environmental contamination, the transfer of contaminants through the food chain, and can hence identify potential health hazards for other animals and for human beings.
4. There is extensive experience of using molluscs (e.g. mussels) as bioindicators in both developed and developing countries. Mussels are particularly useful as they have a widespread distribution and can be sampled relatively easily. In addition, biomonitoring, using mussels, has a distinct advantage over the alternative method of

[2] An analytical method is a procedure used to analyze a sample, to determine the identity and concentration of an individual POP. Analytical methods generally include information on the collection, and storage of samples and define procedures to extract, isolate, concentrate, separate, identify, and quantify components contained in samples. They also provide specific quality control criteria and designate how to report the results. Analytical methods are available for the determination of all 12 POPs.

chemical measurements. Chemical measurements require the collection of large numbers of water and sediment samples, which have the additional difficulty of measuring the usually very low concentrations of POPs present in these samples.

5. Measurements, made using both chemical and bioindicators, are sufficient to determine the concentration of the POPs in the environment, but do not provide information about their effects on living organisms. The effect of POPs on living organisms is related both to the toxicity of each compound or mixture of compounds and to the duration of exposure to POPs.
6. Measurable effects on organisms are therefore used as biomarkers. There are many different biomarkers that occur at many different levels of organization, from subcellular to whole-organisms and ecosystems. Effects at the molecular level tend to occur first, followed by responses at the cellular (biochemical), tissue/organ and whole-body levels. Responses that occur at individual, population and ecosystem level are generally accepted to have ecological relevance and tend to be less reversible and more detrimental than effects at lower levels. Biomarkers are especially useful as an early warning signal of emerging environmental problems, i.e., environmental screening to identify potential pollution/contamination "hot spots".
7. Some biomarkers are very specific in helping to establish cause-and-effect relationships between an exposure to contaminants and biological responses. The results produced by such biomarker studies may be sufficient to replace chemical analysis of the surrounding environment for that particular contaminant. However, highly specific biomarkers are fewer than those which are relatively non-specific.
8. Given the non-specificity of many biomarkers, no one biomarker can provide all the necessary information on exposure to, or the effects of, different POPs present in an environment. Thus, in most environmental assessments, a suite of different biomarkers is appropriate for monitoring purposes.
9. Biomarkers can provide a rapid and cost-effective screening tool, which can complement other testing techniques by significantly reducing the number of samples that would normally be required for a more elaborate, definitive or specific evaluation. Thus, biomarker-based techniques have a major role to play in the overall effort of environmental monitoring and protection.

10. Biomarkers have a huge potential for use in monitoring programmes, but this has yet to be fully realized and adopted widely. Biomarkers, used correctly, are potentially a very useful and cost-effective tool for biomonitoring programmes for pollutants, including POPs, in developing countries. Biomarker programmes need to be designed carefully, for example, special attention needs to be given to the choice of species and methods, to proper collaboration between chemists and biologists, and to the need for internationally-agreed protocols.
11. The choice of an analytical method depends on what question is being asked. If the purpose of an assessment is to measure exact concentrations of one of the 12 POPs, chemical analytical techniques are the only methods that currently meet the criteria of providing exact and comparable data. But, the concentration of POPs, as measured by chemical analysis, is not a good indication of what effect POPs are having on the environment. Nor is chemical analysis a cost-effective tool in detecting "hot spots". Biomarkers have been more effective than chemical methods in identifying the presence of new POPs, e.g. endocrine disruptors, than chemical analysis.
12. New methods of biomonitoring can also offer considerable advantages, for example immunoassays (dipsticks) can be developed for specific POPs and can identify those positive samples that will need further investigation with instrumental analysis. Such immunoassay analyses are cost-effective and can be done by relatively unskilled personnel in the field. They can complement biomarkers in monitoring programmes and have already been used in combination with biomarkers to make rapid assessments of marine pollution.
13. A staged approach in the use of biomarkers and bioindicators for monitoring and measuring POPs is strongly recommended. The first stage would utilise easy-to-measure and cost-effective bioindicators and biomarkers, and test these for a wide range of chemicals from a large number of sites. In subsequent stages, more specific biomarkers would be used to investigate further sites of interest. (The Rapid Assessment of Marine Pollution (RAMP) uses this approach for the monitoring of vulnerable ecosystems and contaminant discharge.)
14. STAP recommends that the GEF should support the wider implementation of a staged approach and that the GEF should support the development of immunoassays for specific POPs.