WORKSHOP REPORT

DEVELOPMENT AND USE OF GLOBAL WATER QUALITY INDICATORS AND INDICES

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LIST OF ACRONYMS AND ABBREVIATIONS

CIESIN	Center for International Earth Science Information Network, Columbia University
DPSIR	Driving Force- Pressure-Impact- Response
EEA	European Environmental Agency
EU	European Union
FAO	Food and Agricultural Organisation
GEMS/Water	Global Environmental Monitoring System (GEMS) Water Programme
GEMStat	GEMS/Water Database
HELCOM	Helsinki Commission
IAEA	International Atomic Energy Agency
MDG	Millennium Development Goals
OECD	Organisation for Economic Cooperation and Development
OSPAR	Commission for the Convention for the Protection of the Marine Environment of the North-East Atlantic
QA/QC	Quality Assessment/Quality Control
SADC	Southern African Development Community
TAG	GEMS/Water Technical Advisory Group
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Commission on Sustainable Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organisation
UNIDO	United Nations Industrial Development Organisation
UNSD	United Nations Statistical Division
WHO	World Health Organisation
WQI	Water Quality Index
WRI	World Resources Institute
WSSD	World Summit on Sustainable Development in Johannesburg 2002
WWAP	World Water Assessment Programme
WWDR	World Water Development Report

EXECUTIVE SUMMARY

As the lead UN body on environment, UNEP had been tasked by UN-Water to lead on water quality and aquatic ecosystem data and information inputs to the World Water Assessment Programme, and the main WWAP output, the World Water Development Report. Part of this task involves developing global water quality indicators and ultimately, a global water quality index.

UNEP delegated this responsibility to GEMS/Water programme, with direction to convene an experts' workshop designed to implement the indicators and index requirements.

The workshop, attended by a small group of selected indicator specialists, was convened in Vienna, Austria (May 4th – 6th 2005) with the objective of reviewing the topic of water quality indicators/indices and making recommendations and suggestions on approaches and actions that GEMS/Water might consider in its future operations.

The workshop discussed and developed recommendations on numerous aspects of GEMS/Water operations, notably:

- The multiple reporting requirements that the GEMS/Water database should support;
- The status and priority of water quality issues which international stakeholders require information on;
- An indicator approach which could form the basis on which GEMS/Water can base its future data storage operations;
- Indicator sets for the priority issues;
- Ideas on universally usable water quality indices that allow for an integrated assessment of water quality;
- A document that can serve as a guideline on water quality indicators for the GEMS/Water network partners; and
- A process and mechanism for the continuous review and development of water quality indicators and indices for international reporting;

This report contains the outcome of the team's review and provides what is considered to be a realistic programme of action for the forthcoming two-year period (2005-2007). The recommendations, which will require decisions and the allocation of resources by GEMS/Water, include proposals to carry out several strategically important actions, notably:

- A pilot study to develop an index to assess the global status of drinking water in source water supplies;
- A follow up pilot study to develop an index to assess the global status of eutrophication, which requires a different approach to that used for the drinking water assessment;
- A desk study to develop an index to assess the capacity of the global water quality monitoring network;
- The production of a guidance document on international water quality indicators and indices; and
- A process of continued review and assessment by a panel comprised of indicator and index development specialists.

1. INTRODUCTION

As the lead UN body on environment, UNEP has been tasked by UN-Water to be the lead on water quality and aquatic ecosystem data and information inputs to the World Water Assessment Programme (WWAP), and its main output, the World Water Development Report. Part of this task involves developing global water quality indicators and ultimately, a global water quality index. UNEP delegated this responsibility to the GEMS/Water programme, with direction to convene an experts' workshop designed to assess and develop an approach to water quality indicators and indices.

In February 2005 the 23rd UNEP Governing Council[1] endorsed GEMS/Water's mandate as being:

- A major global water quality assessment programme;
- A repository for global water quality data and a growing role in the development of water quality indicators to support achievement of water-related goals within the Millennium Development Goals, and the 2002 World Summit on Sustainable Development Implementation Plan; and
- A provider of inputs to the World Water Assessment Programme (WWAP) and the World Water Development Report.

GEMS/Water has organised its operational activities into five core areas: water quality assessments; water quality data and indicators; global data integrity (QA/QC); capacity building; and organisational performance cross-cutting functions[2].

In light of the above, it was considered important that GEMS/Water should review its approach to international reporting with particular reference to the process of developing and selecting water quality indicators and indices to convey information to multiple audiences within the UN network. Consequently, as an initial step, a workshop, attended by a small group of selected international specialists (see **Annexure 1**), was convened in Vienna, Austria (May 4th – 6th 2005) with the objective of reviewing the topic of water quality indicators/indices and making recommendations and suggestions on approaches and actions that GEMS/Water might consider in order to achieve its mandate. This document contains the outcome of the team's review and provides what is considered to be a realistic programme of action for the forthcoming two-year period (2005-2007).

2. WORKSHOP OBJECTIVES AND PROGRAMME

The workshop was designed to discuss and develop recommendations on numerous aspects of GEMS/Water operations, notably:

1. The multiple reporting requirements that the GEMS/Water database should support;

2. The status and priority of water quality issues which international stakeholders require information on;

[1] Proceedings of the Twenty-third session of the Governing Council/ Global Ministerial Environment Forum, Nairobi, 21–25 February 2005

[2] GEMS/Water 2004. Annual Report. 2005 UNEP GEMS/Water Programme. ISBN 92-95039-02-5

3. An indicator approach which could form the basis on which GEMS/Water can base its future data storage operations;

4. Development of water quality indicator sets for the priority issues;

5. Ideas on universally usable water quality indices that allow for an integrated assessment of water quality;

6. A document that can serve as a guideline on water quality indicators for the GEMS/Water network partners; and

7. A process and mechanism for the continuous review and development of water quality indicators for international reporting;

Workshop sessions were held to discuss each of the above topics and discussion was conducted on a group interactive basis so as to develop suggestions and recommendations which GEMS/Water can consider for further follow up and action.

3. WORKSHOP FINDINGS AND RECOMMENDATIONS

3.1 The multiple reporting requirements that the GEMS/Water database should support

GEMS/Water currently provides an open repository for global water quality data that has been contributed to by participating countries and institutions. This has largely functioned as a source of data for individuals and organisations in the development of specific reports and assessments. There are numerous international reporting outlets that GEMS/Water supports, particularly:

- ON behalf of UNEP to UN Agencies (e.g. World Water Assessment programme - WWAP), WHO, FAO, WHO, UNESCO, UNSD, UNIDO, UNCSD, IAEA, etc.)
- International fora and agencies (The World Bank, World Water Forum, regional fora i.e AMCOW)
- International bloc organisations (e.g. OECD, EU, SADC)
- International and regional environmental agencies (e.g. WRI, EEA)
- River Basin Treaties (e.g. OSPAR, HELCOM)
- Academic and technical institutions (e.g. Centre for International Earth Science Information Network)
- Select development projects
- Individual countries (UN member states)
- GEMS/Water publications
- The GEMS/Water and GEMStat websites (www.gemswater.org; www.gemstat.org).

The emergence of the World Water Forums and the establishment of UN-Water, the WWAP with its regular World Water Development Reports (WWDR - 2003[3]) have also provided opportunity for a regular and definitive international reporting system on the status of global water resources. GEMS/Water is seen as the main sources of environmental water quality data for the WWDR series and for other forms of reporting through the UN bodies.

[3] UN World Water Development Report 2003 (WWDR) ISBN: 92-3-103881-8. UNESCO, Paris. www.unesco.org/water/wwap/wwdr/index.shtml

The WWDR (2003) did not focus specifically on water quality nor made water quality a priority topic in its list of issues and topics, with more focus on water availability (quantity). There is thus a need to introduce additional water quality information, including the development of composite ranking indices, into the WWDR series, as well as other international reports (e.g. The 2005 Millennium Ecosystem Assessment[4] and the 2004 WHO/UNICEF Report on Water and Sanitation[5]).

These above-mentioned reporting systems do not focus specifically on water quality, but regard it as a key component that is inter-related to other environmental issues (social, economic and ecological). The majority of international assessments treat water quality according to issue-based and user-based perspectives (e.g. acid rain, eutrophication, toxic waste, drinking water usage, recreational water usage, agricultural usage etc.).

Workshop Suggestions and Recommendations

It is felt that GEMS/Water should take a more proactive approach to international reporting by devoting more effort towards producing assessments on the status and trends of priority international environmental water quality issues. Such assessments would serve to highlight the importance of water quality throughout the world and place GEMS/Water as the authoritative source of water quality data and information. In developing a focus on indicators and indices, GEMS/Water should consider the following points (some of which are also dealt with later on in this report):

- A process should be put in place to deal with data and the development and assessment of indicators and indices that serve for each assessment. This aspect is dealt with in greater detail in sections 3.4 and 3.5 of this report;
- Assessments will always be situational and therefore the content and treatment will depend on the issue and topic that is selected. However, there is a need for GEMS/Water to have input into the way in which other organisations make use of data from the GEMS/Water database, thereby ensuring not only quality control of the data, but also a form of quality control on its usage. The policy could perhaps be one in which GEMS/Water reviews and makes comments on assessment reports that have been generated using its data;
- There is a need for GEMS/Water to gain better knowledge of the water quality reporting outputs of the organisations that request and use information. This provides an indication of water quality indicators that other organisations are using for purposes of reporting;
- The process of producing assessments and developing feasible indicators should also serve to reinforce the importance for monitoring by parties within the GEMS/Water network.

3.2 The status and priority of water quality issues

GEMS/Water, in its operational guide, cites seven water quality issues of significance at the global and/or continental or sub-continental level that are considered to be important for water quality monitoring. These are:

[4] World Millennium Ecosystem Assessment Reports. www.millenniumassessment.org/en/products

[5] WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2004. Meeting the MDG drinking water and sanitation target: a mid-term assessment of progress, 2004. (ISBN 92 4 156278 1)

1. Organic wastes from municipal sewage discharges and agro-industrial effluents;
2. Eutrophication of surface waters as a result of point and non-point input of nutrients and organics;
3. Irrigation areas that are threatened by salinization and polluted irrigation return waters;
4. Agro-chemical use, fertilizers and pesticides leading to surface and groundwater contamination;
5. Industrial effluents containing a variety of toxic organics and inorganics;
6. Mining effluents and leachates from mine tailings affecting surface and groundwaters on a large scale;
7. Acidification of lakes, rivers and even groundwaters resulting from the long-range atmospheric transport of pollutants.

However, over the years there have been many other water quality related issues that have been raised at the global level. A comprehensive overview of global water quality issues is given in the UNCSD background paper by Helmer *et al.* (1998)[6]. The priority issues that the authors cite are:

- Healthy ecosystems maintenance;
- Safeguarding drinking water supplies (specially relevant now in terms of the Millennium Development Goal on the delivery of safe drinking water);
- Food security and the impacts of agriculture; and
- Integrated water management, which takes into account water quality and quantity.

International priorities are also reflected by the indicator lists that have been posted by certain international agencies for countries to monitor and submit information (see **Annexure 2**), as well as the content of databases that are involved with global environmental reporting and that contain water quality information (see **Annexure 3**).

The quality of water in any water resource (lake, reservoir, river, wetland, estuary, aquifer) influences the way in which the water is used for activities such as drinking, swimming, domestic and industrial purposes. There is global concern that water resources are unable to maintain their fitness for use (in terms of changing water quality) for a multiplicity of uses, more specifically:

- Supplying drinking water;
- Recreation and tourism (swimming, boating);
- Irrigating crops and watering stock;
- Industrial processes;
- Navigation and shipping;
- Production of edible fish, shellfish and crustaceans;
- Protection of aquatic ecosystems;
- Wildlife habitats; and
- Scientific study and education.

[6] Richard Helmer, Edwin D. Ongley, Norman E. Peters 1998 Water Quality - A Global Concern. Background Paper, United Nations Commission on Sustainable Development.

Workshop Suggestions and Recommendations

Although there might be a desire to have global assessments done of many of the above-mentioned water quality issues/topics, in many cases it is simply not feasible at the global level because of a general lack of data required to make an adequate assessment. In terms of selecting priority water quality issues that GEMS/Water might consider for the preparation of assessments, there are many selection criteria that need to be considered. However, the more important of these are:

- The position of the issue/topic on the international agenda;
- Commonality of the issue/topic throughout countries of the world;
- The relationship to human health and well-being
- Data acquisition aspects, and more specifically considerations of spatial representivity, global comparability, and the ability of the individual countries to provide data; and
- The anticipated return on investment in terms of time and resources required to do the assessment.

In developing issues/topics that GEMS/Water might consider as priorities for undertaking assessments, there are several assessment approaches that are proposed. Each assessment approach is outlined below with comments that were raised in the workshop. For each approach, unless stated, the topics or issues for assessment are listed in terms of the working group's perceived priority for assessment. It should be emphasised that although these topics are numbered the order cannot be considered to be a definitive ranking.

User –based Issues and Topics

This is where an assessment is done based on the status of water quality relative to a specific use and making use of guideline values and standards. This approach typically applies a common guideline to water quality data to determine if the water is within a quality suitable for the target use. Topics considered to be a priority were identified as:

1. Protection of source water quality for domestic use (drinking water, abstraction etc)
2. Protection of aquatic life/biodiversity/ecosystem health. Mechanisms are is in place to assess WQ with respect to ecosystem health, but biological indicator data are not yet available on a global scale. Application of a user-based approach to assess the quality of water for aquatic life is very difficult, especially on broad scales, considering site-specific differences in natural water quality. It is likely that this is not feasible for global assessments.
3. Protection of water used for agriculture. Guidelines will need to be evaluated for specific crops/functions (e.g. irrigation and livestock watering)
4. Protection of water used for recreation/contact (global guidelines might be used).
5. Protection of water used for aquaculture / fisheries (aquaculture guidelines might be used).
6. Protection of water used for different industries (industries have variable water quality requirements)

System-based Issues and Topics

This is where the assessment is done on specific water resource systems in order to describe the condition or trends in a specific area or region. Assessments should take into account the local and/or regional situation. Systems of importance include:

1. Basins/catchments/watersheds, including their
    a. Groundwater /springs

b. Rivers
c. Lakes
d. Wetlands
e. Deltas/Estuaries

There is a need to see comparative regional and basin assessments for systems such as the Nile, Orange River Basin, Zambezi, Amazon, Rhine, Hudson, McKenzie, Mississippi, Great Lakes/St Lawrence, Murray Darling, Lake Victoria, Mekong, Niger amongst others globally.

2. Countries/regions/administrative boundaries
3. Climatic / Ecozones
4. Coastal areas affected by land-based pollution

Prioritisation of the value and/or importance of performing assessments at one or several of the above scales is difficult, and it was generally agreed that the assessment should be conducted based on the information needs of the reporting agency.

Theme-based Issues and Topics

This is an assessment where a specific type of pollutant is involved and for which status will be based on a reference level (background state). Priority theme-based issues include:

1. Eutrophication (assessment should probably be based on extent of enrichment - i.e. nutrients (N, P) and focus on a reference condition as well as changes over time).
2. Salinization (Conductivity would be best indicator and use a reference condition approach or an evaluation of changes from historical conditions).
3. Sedimentation/siltation/Erosion (suspended matter in river stations will give an indication of water quality. There are many problems associated with the assessment of sedimentation/siltation/erosion, including issues around such as seasonality and regulated versus unregulated rivers and sampling frequency would need to be high in order to detect high sediment/flow events).
4. Acidification (changes in pH over time). Assessments will need to compare to reference states as well as examine historical patterns. A long-term data set will be required. Acidification is a fairly localised regional problem/issue.
5. Microbial contamination (unfortunately this is low in priority because assessment is deemed to be unfeasible due to lack of data. Because microbial contamination is localized, global assessment will be difficult. However, should data availability improve assessment of water quality for this theme should be considered).
6. Toxics (e.g. POPs, endocrine disruptors - assessment would be very difficult because of the wide range of potential toxics and limited data availability. A lot of toxics analysis should be examined at sediments rather than water column)
7. Climate change (most climate change issues will probably be water quantity issues. However, if sea level rises there might be saltwater intrusion issues in the interface zone).
8. Radioactivity (probably very little data available and very localized, primarily in sediments).

Stressor-type Issues and Topics

This is where a specific anthropogenic activity is considered to be a stressor that affects water quality in a major way. Stressor-based issues are very similar to theme-based issues except they are more directly related to anthropogenic influences. In order to be able to properly assess the effects of different stressors on water quality, stations must be specifically chosen where these effects can be seen.

1. Urbanization (e.g. runoff, wastewater, storm water)
2. Agriculture
3. Forestry
4. River regulation (dams / diversions/interbasin transfers)
5. Industry (pulp and paper, oil and gas, hydroelectricity, etc)
6. Mining
7. Aquaculture/fisheries
8. Climate change
9. Conflict
10. Natural disasters

Cross-cutting Issues and Topics

Cross-cutting issues and topics are those that are considered to have major influences on water quality. These are not placed in any ranking order.

- Runoff
- Wastewater
- Non point sources and point sources of pollution
- Climate (environmental) vulnerability and change
- Aquatic life/ biodiversity/ecosystem health
- Water Quantity/Flow/Loads

Overview Summary

Development of a GEMS/Water approach for selection of water quality indicators and for conducting targeted global assessments of water quality requires ground-truthing on a pilot scale. In light of the many approaches and the many topics outlined above, it is felt that GEMS/Water should initiate a pilot project on a topic for which there is a high level of international political interest and for which there is a high probability of delivering a useful assessment. The topics that are recommended for pilot assessments (in order of priority) are:

- ***Source water quality for domestic use (with special reference to drinking water)***. This topic was selected because it is of obvious significance to human health, could be conducted on a global scale, and the approach for the assessment would be user-based and involve application of common guidelines such as those from the WHO across multiple water quality stations. An outline of how this could be approached is given below in section 3.5.
- ***Eutrophication*** - This topic was selected because eutrophication is also a global issue, data exists for an assessment, and a "reference condition" type of approach would be used for the assessment which differs from the user-based approach to be used for the drinking water assessment described above.

3.3 Indicator Approaches

Since the 1992 Rio UNCED Conference and its recommendations through Agenda 21, there has been a proliferation in activities that have attempted to develop and define indicators for measuring and reporting on sustainable development. For purposes of this report the following definitions apply[7]:

[7] UN World Water Development Report 2003 (WWDR) ISBN: 92-3-103881-8. UNESCO, Paris.

A variable, determinand or parameter ***is an observed datum derived by using statistics or monitoring***.

An indicator ***comprises a single datum (a variable) or an output value from a set of data (aggregation of variables), describes a system or process such that it has significance beyond the face value of its components***.

An index ***is a mathematical aggregation of variables or indicators, often across different measurement units, so that the result is dimensionless***.

The major international indicator development models appear to have been shaped by four approaches[8]. These are:

1. Bottom-up approach

A bottom-up approach uses an information pyramid, in which the logic is to aggregate available primary data along several hierarchical levels into indicators using intuitive and mathematical approaches. Is used when there are lots of data available.

2. **Top-down approach**, which follows the logic down from vision to themes to actions to indicators

This draws from the Logical Framework (log frame) approach, which is a programme management tool that serves purposes in both design and monitoring within programme cycle management. A log frame follows a generalized structure where the goal of an intervention is structured according to its purpose, outputs and specific activities. Indicators, whether quantitative, qualitative or time-based, are in all cases set at all levels of the log frame from goal down to activity. The indicators are based on achievement of a goal or objective e.g. The Millennium Development Goals.

3. **Systems approach**, which bases indicators on a comprehensive analysis of system inflows and outputs

A system approach analyses the inflows, stock and outflows of an issue before defining indicators. It draws from the concept of system dynamics and offers a way forward in understanding the behaviour of the system over time. The approach adheres to the notion that "all systems depend to some degree on the resource-providing and waste-absorbing capacities of their environment".

The systems approach has been applied in developing sustainability indicators and relies on specific indicators dealing with human systems (including social and individual development and governance), support systems (including economics and infrastructure), and natural systems (including resources and environment). Although the approach is seen as very promising, it is complex and often considered at a stage of development where it still is 'too academic' to address real-world problems.

4. Cause-effect approach

The cause-effect approach is one of the most widely used approaches to indicator development. Also considered a milestone, the pressure-state-response (PSR) conceptual

[8] UN World Water Development Report 2003 (WWDR) ISBN: 92-3-103881-8. UNESCO, Paris.

framework was first introduced by the Organization for Economic Cooperation and Development (OECD) in 1994. This enabled trade-offs and the linking of environmental, economic and social indicators (OECD, 1994). Following the PSR framework of the OECD, several cause effect classifications have been developed:

- The Driving force-Pressure-State-Impact-Response (DPSIR) framework is used by the European Environmental Agency, United Nations Environment Programme (UNEP).

- The Driving Force-State-Response (DSR) framework of the United Nations Commission on Sustainable Development was used for the indicators of Agenda 21.

- The Pressure-State-Impact-Response (PSIR) framework is mostly used in the Netherlands.

- The Driving Force-Pressure-State-Exposure-Effects-Action (DPSEEA) framework is used in the burden of disease studies of the WHO.

There have been numerous international indicator/index initiatives over the last decade (see Annexure 4 with examples of indicator and index initiatives – taken from WWDR- 2003). Many of them have components, which relate to water quality, but none of them have focussed on water quality as a special topic. The WWDR 2003 report makes use of several of these frameworks in its reporting approach.

Workshop Suggestions and Recommendations

The key to any future assessment and reporting approach is to develop an issues-based approach that can be applied to a variety of water quality issues at the national and global levels (see previous section 3.2). In the context of the DPSIR indicator framework, it is emphasised that although water quality variables describe the "state" of water in a specific water resource, they can also reflect "impacts" when compared against reference values, guidelines and criteria, and historical levels. This is best illustrated in Figure 1 that shows a schematic diagram in which the DPSIR indicator framework is superimposed over the management components of a generic water resource system. GEMS/Water, in its assessments and its database, should focus on indicators that measure "state". Impacts might be inferred by examining changes in state relative to historical values, guidelines, or reference conditions. At the international and global level, expansion of any assessment into illustrating and explaining all the causes and effects of water quality (e.g. Driving Forces, Pressures, Impacts, Response) is not realistic in terms of feasibility.

The most realistic approach will be to evaluate the trends and status in water quality against guideline values for a specific usage (e.g. drinking water) or against a reference level (e.g. for eutrophication) for the particular water resource. In the case of the former approach there is a linkage with impacts as it will be a user-based assessment.

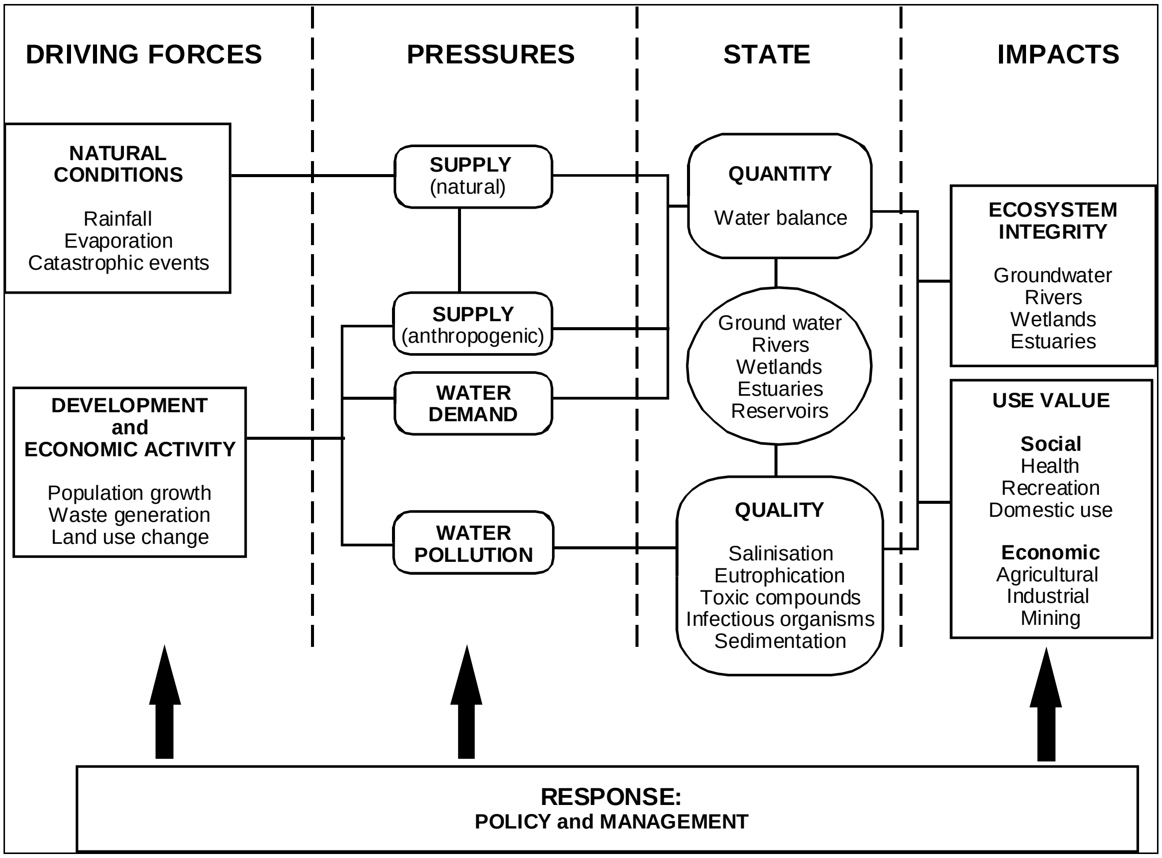

Figure 1: The DPSIR indicator framework superimposed on components of a water resource management system (taken from Walmsey 2002[9]).

3.4 Indicator Sets for the Priority Issues

All of the issues and approaches that have been outlined in section 3.3 require the development of indicator sets and indices to describe their status. Although there are several indicator frameworks that can be used, many indicators will be common and applicable to each the separate frameworks. Indicator sets will therefore be situational depending on the topic and the availability of data.

Workshop Suggestions and Recommendations

The selection of indicators for any particular use, theme or system is dependent on firstly defining the information requirements of the user and then matching these up with criteria that deal with the availability of, and feasibility in acquiring, the necessary data. It is however suggested that lists of potentially useful indicators are contained in the annexures of the Guidance document that is proposed in section 3.6 of this workshop proceedings.

[9] Walmsley Jay J 2002. Framework for measuring sustainable development in catchment systems. Environmental Management Vol. 29, No. 2, pp. 195–206

3.5 Global Water Quality Indices

In simple terms, a Water Quality Index (WQI) is a single number that expresses water quality by integrating measurements of selected water quality parameters. Because of the complexity in analysing and assessing water quality, as well as the enormous amount of data and information that has to be interpreted, the use of indices has become increasingly more popular to identify trends and integrated changes in water quality (**see Annexure 4**). WQIs have the potential to summarize complex scientific information on water quality into a simpler form for assessment, communication, and reporting purposes.

Some of the advantages of indices are:

- WQIs can be used to show water quality variation both spatially and temporally;
- Provide a simple, concise and valid method for expressing the significance of regularly generated laboratory data;
- Aid in the assessment of water quality for general uses;
- Allow users to easily interpret data;
- Can identify water quality trends and problem areas;
- Provide a screening tool for further evaluation;
- Improve communication with the public and increases public awareness of water quality conditions;
- Assist in establishing priorities for management purposes.

Some of the limitations are:

- Provide only a summary of the data;
- Cannot provide complete information on water quality;
- Cannot evaluate all water quality risks;
- Can be subjective and biased in their formulation;
- Because of differing climates and conditions they are not universally applicable;
- Are based on conceptual generalisations that are not universally applicable;
- Have the prerequisite of requiring groups/sets of indicators in their formulation;
- Perfectionist scientists and statisticians tend to disapprove of, and criticise, methodology, thereby eroding credibility as a screening management tool.

Workshop Suggestions and Recommendations

There is a general acceptance around the globe that information for decision-makers needs to be aggregated as much as possible in order to maximise the value in interpretation. Thus, many countries have accepted that WQIs have great value as a screening method and that individual indicators can be used to provide further detail beyond the screening. Accordingly, there are many indices being used as water quality management tools (**see Annexure 4**).

Standards and Guidelines-based assessments

One of the most popular approaches to the use of indices is that of comparing the deviation of water quality data against a set standards or guideline values and reporting an index which gives a composite measure of deviation against a reference value (e.g. unpolluted water) or a standard or guideline value (e.g. drinking water quality guideline values). This approach is advocated for GEMS/Water and there is a need for GEMS/Water to explore the development of an index by initiating a pilot assessment on a topic which has high-level political interest, and which has a good chance of achieving valuable results.

The topic proposed is ***Source Drinking Water Quality*** and the suggested approach is outlined in the steps below:

1. Review global and national WQ guidelines/standards
2. Generate master variable list of indicators that will be used in the analysis
3. Select guidelines to use for later evaluation
4. Determine candidate variable list based on expertise
5. Evaluate guideline gaps
6. Assess data availability
7. Select stations to use based on the GEMS/Water monitoring stations (e.g. trend, global flux, baseline)
8. Calculate index on a per station basis. Index will be based on the extent of deviation from drinking water guidelines (e.g. World Health Organisation)
9. Evaluate indices on a per station basis
10. Aggregate results as appropriate (country/basin/etc) and apply weights if deemed appropriate
11. Prepare Write-up

The production of an initial global assessment of the state of global drinking water resources could be realistically achieved within a period of eight months (**see Annexure 5**).

Reference-Conditions based Assessments

Guidelines and standards are not available for all water quality variables and all water uses. For example, there are virtually no international guidelines that set recommended levels for phosphorus in freshwater, even though phosphorus is widely recognized as an important driver of freshwater eutrophication worldwide. The development of composite indices for many issues and themes is complicated by the lack of available or consistent guidelines for many water quality variables.

In cases where guidelines are not available for some or all of the water quality variables of interest, the approach to developing indices outlined above must be modified to include an evaluation and quantification of natural background or reference levels of the variables of interest (these steps would be added to Step 5, above). The index would then be calculated based on deviations of observations from the 'natural' range of water quality variables, rather than on deviations from guideline values, on a per-station basis (Step 8). Although the steps for developing a composite water quality index based on reference-condition ranges are clear, the implementation of these steps will be limited by the availability of data to adequately quantify natural background conditions. Thus, step 6 in the above framework will be a critical step to determining the feasibility of developing a water quality index based on a reference-condition approach.

Taking into account the need to test a reference condition case study, it is also proposed that a follow up assessment on ***eutrophication*** be carried out after the drinking water assessment. This should only be done after a thorough evaluation of the approach has been carried out by an indicator technical panel (see section 3.7).

This approach is more complicated than the approach used for drinking water (i.e., application of common WHO guidelines across multiple monitoring stations). However, development of this approach is critical as it is one that applies across multiple theme and stressor-based water quality issues. If this approach can be developed and rigorously tested using the GEMS/Water database, it will result in a significant achievement and advancement of the use of water quality indices.

Index of Water Quality Monitoring Capacity

An additional aspect involving index development is that of developing a better knowledge and understanding of the characteristics and water quality monitoring capabilities of UN-member countries. It was proposed during the 2nd TAG (convened in Austria in May 2005) that GEMS/Water develops and tests a Global Data Integrity Index that assesses water quality monitoring capabilities of UN member countries, and the quality of data being submitted to GEMS/Water. This will identify gaps and needs in the global water quality monitoring network. Such an index would be valuable in providing GEMS/Water with a tool by which it can decide on where it should focus its resources and capacity building actions, as well as providing an indication of the quality of the sources of data that are present in the GEMS/Water database. It is suggested that an index, comprised of certain attributes (see list below), be developed in collaboration with National Focal Points, and each country requested to rate itself according to these attributes, which could include:

- Existence of a water quality monitoring system
- Scope and extent of network coverage
- Availability of water quality guidelines or standards
- Increase/decrease in water quality investment
- Frequency intensity of monitoring
- Data quality assurance and quality control (QA/QC)
- Database management system
- Human resources/expertise
- Assessment and Reporting
- Participation in GEMS/Water programme activities

3.6 Guidance Document on Water Quality Indicators and Indices

Indicators represent what is reported on to the recipients of the many reports that are prepared and received by the respective audiences. To date there have been many reports that have focused on sustainable development indicators and general state of the environment. Although, it is implicit that indicators are the basis of water quality monitoring, there are few guidance documents, which outline how water quality indicators and indices should be developed and used to assess water quality on a global scale.

Workshop Suggestions and Recommendations

The working group felt that there is a strong need for GEMS/Water to produce a guidance document that focuses on global water quality assessment including relevant water quality indicators and indices. In preparing a guidance document, GEMS/Water should consult extensively with individuals and organizations that have expertise in different associated fields (e.g. drinking water and human health, agricultural experts, industry, recreation etc.).

The envisaged contents of the document could contain the following sections:

1. Introduction, context, purpose
2. Concepts and definitions of indicators and indices (descriptions of approaches)
3. Review of where indicator/indices have been applied - advantages, disadvantages etc
4. The process of developing and using indicators and indices (i.e. linkages with policy and management and the monitoring system); emphasize that selection of variable list is a consultative process; describe reference versus guideline approaches
5. Some examples and case studies
6. Conclusions and Recommendations

Appendix 1: Indicator sets for different issues/users.
Appendix 2: List of variables in GEMS master list: what they tell us? how can we use them? Strength and weaknesses of variables as indicators.

Appendix 3: Summary of guidelines.
Appendix 4: Summary table of GEMS variables: country coverage, station coverage, basic statistics (min., max., mean, median etc.).

Development of sections of the guidance document could begin immediately and the complete document could be built up as more experience is gained from the assessments.

3.7 A Process and Mechanism for Continuous Review

The development and use of indicators is viewed as a continuous and iterative process (see Figure 2 below).

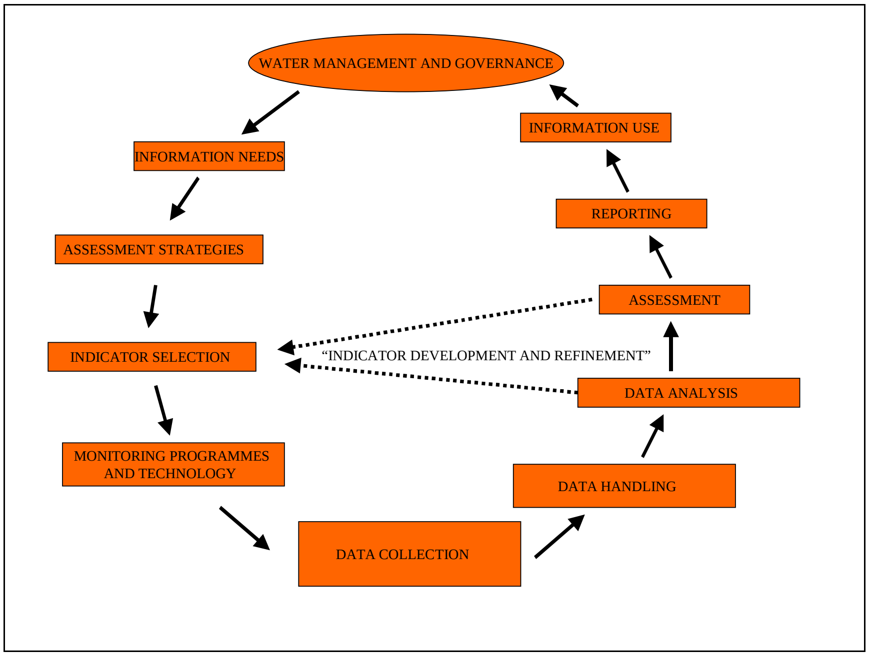

Figure 2: Schematic diagram to illustrate the iterative nature of indicator selection and development. Ideally, only "accepted" indicators should be incorporated into the reporting process so as to minimise information overload and improve decision-making.

The diagram indicates that indicator selection is a step that follows after the information needs of users have been defined. The process of indicator selection therefore needs a continuous involvement with users as to what information they require, followed by the selection and testing of the indicators. There is also a final important step (not depicted in the figure) and that is evaluation of the reports that are being received by the decision makers and stakeholders.

Workshop Suggestions and Recommendations
In the case of technical involvement it is essential that assessments using water quality indicator/indices should get sound technical evaluation and review. This should be done on a continuous basis by persons who are involved with the technical development of water quality indicators and indices. The evaluation at the administrative and political level is one that is best done following the production of assessment reports when the final information product is presented for consideration and comment.

GEMS/Water should have a defined programme of actions that contributes to the development of international water quality indicators and indices. A tentative programme with the multiple elements that incorporate most of the suggestions and recommendations from the workshop is presented in Gantt Chart form in **Annexure 5**. This has only been done to cover the period up to beginning of 2007, as it is of little value to project beyond this period.

It is recommended that GEMS/Water continue to benefit from the experience and background of the experts who attended this first workshop in Vienna, as a means to evaluate and review the programme outputs, as well as to direct the furthering of international water quality indicators and indices. This group would constitute an expert group on global water quality assessments. The specifications for the group could be:

- Objectives would be to evaluate and advise on outputs, as well as programme planning
- Not be more than 10 persons with technical expertise to cover topics such as drinking water, eutrophication, ecosystems and biodiversity, agriculture, indicators and index development processes, water quality/chemistry
- There might also be institutional representation e.g. European Environment Agency, WWAP, National Focal Points, and Regional representation
- Other persons could be invited to attend specific meetings, depending on their availability and the topics to be discussed.
- The meeting frequency could be once per 12-18 months.

If GEMS/Water proceeds with the suggested programme some of the first tasks of the group could be to review the progress and products of the drinking water assessment, the eutrophication assessment and the guidance document on indicators and indices.

ANNEXURE 1

UNEP GEMS/WATER INDICATORS WORKSHOP PARTICIPANTS
4th – 6th May 2005

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ANNEXURE 2

INFORMATION AND INDICATOR DATA REQUIREMENTS OF SOME INTERNATIONAL REPORTING ORGANISATIOns

	Fresh Water Indicators	Sea Water Indicators	Wastewater Indicators
EU	Nutrient (N+P) use (eutrophication equivalents) (S)	Eutrophication (S)	Water treated/water collected (R)
	Groundwater abstraction (P)	Fishing pressure (P)	
	Pesticides used per hectare of utilized agriculture area (P)	Development along shore (P)	
	Nitrogen quantity used per hectare of utlised agriculture area (P)	Discharges of heavy metals (S)	
	Emissions of organic matter as BOD (P)	Oil pollution at coast and at sea (S)	
		Discharges of halogenated organic compounds (S)	
MAP/ Blue Plan	Access to safe drinking water (R)	Global quality of coastal waters (S)	Wastewater treatment rate before sea release for coastal agglomerations over 100 000 inhabitants (R)
	Exploitation index of renewable resources (S)	Density of the solid waste disposed in the sea (S)	Share of collected and treated wastewater by the public sewerage system (R)
	Non-sustainable water production index (S)	Coastal waters quality in some main "hot spots" (S)	Share of industrial waste water treated on site (R)
	Share of distributed water not conform to quality standards (S)		
	Water global quality index (S)		
	Existence of economic tools to recover the water cost in various sectors (R)		
	Drinking water use efficiency (R)		
OECD	River water quality in terms of dissolved oxygen and nitrate concentration. (S)		Sewerage and sewage treatment connection rates (R)
	Intensity of use of freshwater resources (freshwater abstractions) (P)		
	Public water supply and price – abstractions for public supply per capita and water prices (R)		
UN[10]	Annual withdrawals of ground and surface water (P)	Population growth in coastal areas (P)	Wastewater treatment coverage (R)
	Domestic consumption of water per capita (P)	Discharges of oil into coastal waters (P)	
	Groundwater reserves (S)	Releases of nitrogen and phosphorous to coastal waters (P)	
	Concentration of faecal coliforms in freshwater (S)	(Maximum sustained yield for fisheries) (S)	
	Biochemical oxygen demand in water bodies (S)	Algae index (S)	
	Density of hydrological networks (R)		

[10] United Nations (1996) Indicators of Sustainable Development Framework and Methodologies . United Nations, New York.

ANNEXURE 3

DATA SOURCES FOR INDICATORS

Statistical Commission
Thirtieth session
New York, 1–5 March 1999
Item 5 of the provisional agenda*
Environment statistics

Water

1. Access to safe drinking water WHO IO N 91 A 1995 Reproduced in the forty-second edition of the *Statistical Yearbook* (United Nations publication, Sales No. E.97.XVII.1)

2. Acidification of freshwater bodies CCIW NA N 58 3Y 1995

3. Concentration of cadmium CCIW NA N 58 3Y 1995

4. Concentration of faecal coliform CCIW NA N 58 3Y 1995

5. Concentration of lead CCIW NA N 58 3Y 1995

6. Concentration of mercury CCIW NA N 58 3Y 1995

7. Concentration of pesticides CCIW NA N 58 3Y 1995

8. Renewable water resources UNSD IO N A First attempt at data collection via UNSD questionnaire

9. Water abstraction UNSD IO N A First attempt at data collection via UNSD questionnaire

10. Water supply by activity UNSD IO N A First attempt at data collection via UNSD categories questionnaire

11. Water quality of selected rivers UNSD IO N A First attempt at data collection via UNSD (biochemical oxygen demand, questionnaire chemical oxygen demand (BOD, COD))

12. Water quality of selected lakes UNSD IO N A First attempt at data collection via UNSD (BOD, COD) questionnaire

13. Waste-water treatment UNSD IO N A First attempt at data collection via UNSD questionnaire

Air

14. Emission of sulphur dioxide UNSD IO N A First attempt at data collection via UNSD (SO) questionnaire 2

15. Emission of nitrogen dioxide UNSD IO N A First attempt at data collection via UNSD (NO) questionnaire 2

16. Ambient concentration of SO UNSD IO N A First attempt at data collection via UNSD 2 questionnaire

17. Ambient concentration of NO UNSD IO N A First attempt at data collection via UNSD 2 questionnaire

18. Ambient concentration of UNSD IO N A First attempt at data collection via UNSD suspended particulate matter questionnaire (SPM)

19. Ambient concentration of ozone GEMS IO N A

20. Ambient concentration of carbon monoxide (CO) GEMS IO N A

21. Consumption of chlorofluorocarbons (CFCs) OS/UNEP IO N A Data available for most countries as part
of reporting obligations to the Montreal Protocol on Substances that Deplete the Ozone Layer

22. Emission of methane (CH_4) UNFCCC IO N 38 A 4

APPENDIX 4

SOME CURRENT INTERNATIONAL APPLICATIONS OF WATER QUALITY INDICES

International

The Environmental Sustainability Index (ESI)

This is a collaborative project involving the Yale Center for Environmental Law and Policy, the Center for International Earth Science Information Network (CIESIN) at Columbia University and the World Economic Forum. The ESI is a composite index tracking a diverse set of environmental, socioeconomic, and institutional indicators that characterize and influence environmental sustainability at the national scale. It was produced in 2001 and 2002, and the latest version is for 2005. Plans are to update it every 3-4 years. It makes use of a water quality component (variables include dissolved oxygen concentration, electrical conductivity, phosphorus concentration and Suspended solids) to compute a ranking and compare countries. Its use in the WWDR 2003 report to compare the status of countries was controversial because of the ESI's use of imputed data (the WWDR dropped annotations indicating which countries had imputed data and which did not). For more on the methodology used to develop the water quality indicator, view Appendices A and C of the 2005 ESI report (www.yale.edu/esi/).

United States of America (http://www.epa.gov/OW/states.html)

Of interest is the fact that in the USA in 1978 ***"one-fifth of the State and interstate agencies (12 out of 60 agencies) were classified as users of water quality indices. Of the 51 State agencies (including the District of Columbia), 10 States (20 percent) were classified as index users. The National Sanitation Foundation Index was the most commonly used index, accounting for 7 of the 12 index users. The remaining agencies use Harkins' index or various user-developed indices***".

Almost 30 years later, current approaches include**:**

- NSF index for sanitation value (this has been used and applied for more than 30 years in almost all states)
- General water quality particularly for recreational value in many states and counties (e.g Ohio, Colorado, Indiana, Oregon, Florida etc.)
- USA EPA index of watersheds aimed at assessing percent of Assessed systems (Rivers, reservoirs, lakes) meeting all designated uses is applied across the country in every state.

Canada (www.ccme.ca/assets/pdf/wqi_techrprtfctsht_e.pdf)

Canada has adopted an approach that uses one or more measures of three attributes of water quality, measured against objectives appropriate for the use of the water. The index thus provides a measure of the deviation from compliance against standards/guideline values for recognised water quality variable that have been developed for specific uses.

There are three factors in the index, each of which has been scaled to range between 0 and 100. It makes use of 3 factors:

1. **Scope,** which represents the extent of water quality guideline non-compliance over the time period of interest.

2. **Frequency** represents the percentage of individual tests that do not meet objectives ("failed tests"):

3. **Amplitude** represents the amount by which failed test values do not meet their objectives.

The index can be done for whatever variables are being measured and relevant to a specific water use. The index is currently being tested throughout Canada and has shown promise as a monitoring and assessment tool.

Malaysia (http://agrolink.moa.my/did/river/sgklang/sgklang_wqi.htm)

The Malaysian WQI system is used as a preliminary means of assessing a water body for compliance with the standards adopted for five designated classes of beneficial uses. It makes use of six variables each of which is given a different factor rating value. It thus provides a general rating for monitoring, use and management.

India (http://www.gisdevelopment.net/application/environment/water/ma03123abs.htm)

An index that monitors groundwater against compliance deviation from WHO drinking water standards.

New Zealand (www.iwaponline.com/wst/04305/wst043050285.htm)

There is a water quality index that is based on recreational usage using 10 water quality variables.

Australia (see www.melbournewater.com.au/content/water_cycle/rivers_and_creeks)

Melbourne Water uses a stream water quality index that is based on an integrated value of water quality as set against water quality target values. The Index of Stream Condition is designed to provide an overall integrated measure of the environmental condition of streams. It amalgamates information on the naturalness of the flow regime, water quality, condition of the channel and riparian zone and the invertebrate communities living in the stream.

The index contains five sub-indices and provides a summary of the extent of change from natural or ideal conditions for each of the sub-indices.

Hong Kong (http://www.epd.gov.hk/epd/english/environmentinhk/water/river_quality/)

The Hong Kong WQI makes use of three variables and classifies river water quality into 5 categories according to the level of organic pollution.

United Kingdom (http://www.defra.gov.uk/news/2004/041005a.htm)

The UK makes use of a river water quality indicator that is an aggregate of chemical (dissolved oxygen, biochemical oxygen demand and ammonia). and biological variables in relation to river length and class classification.

Scotland makes use of a drinking water quality 1000 Index — the closer the figure is to 1000, the better the quality of the water. The index covers regulatory compliance at customers' taps with 10 key drinking water parameters: Total coliforms; Faecal coliforms; Colour; Turbidity; pH; Aluminium; Iron; Manganese; Lead; and Trihalomethanes (THMs).

South Africa (www.deat.gov.za/soer/reports/ehi/ehi_ch4.pdf)

Have developed one for estuaries making use of impairment status relative to oxygen status; eutrophication; health aspects; physical characteristics; and dissolved substances.

South Africa also uses a biotic index (SASS) based on invertebrates as a measure of the quality of its surface waters.

European Union Countries

Many of the EC countries report trends in their water (river) quality often in terms of national classification schemes. Whilst national classification schemes are not directly comparable between countries, the trend information can be aggregated/formulated into an indicator (index?) of general European river quality.

There are, however, significant limitations to the information for European policy makers provided by this approach including:

- River water quality is not directly comparable between countries;
- The scale and locations of water quality problem areas (e.g. in terms of relatively high nitrate and ammonium concentrations), and which may require further European action or measures (e.g. structural funds for improvements), cannot be identified;
- National classifications and/or reported trends can be based on relatively few rivers/stations perhaps focusing on the poorer quality rivers and therefore do not give a representative view of quality in countries and hence Europe;
- National classifications are expressed as either river lengths or by number of stations in each class, again making the comparison between countries difficult.
- Reporting periods and lengths between classifications vary greatly, and therefore timely, reliable and comparable trends cannot be obtained; and
- Relatively few countries have national classification schemes or report trends for lakes, transitional and coastal waters.

ANNEXURE 5

ENVISAGED SCHEDULE FOR PROPOSED ACTIVITIES

(separate GANTT chart)