UNEP

A Snapshot of the World's Water Quality: Towards a global assessment

Executive Summaries

ISBN Number: 978-92-807-3555-0

Job Number: DEW/1975/NA

Disclaimers

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of UNEP concerning the legal status of any country, territory or city or its authorities, or concerning the delimitation of its frontiers or boundaries. For general guidance on matters relating to the use of maps in publications please go to: *http://www.un.org/Depts/Cartographic/english/htmain.htm*

Mention of a commercial company or product in this publication does not imply endorsement by the United Nations Environment Programme.

Reproduction

Suggested Citation

UNEP 2016. A Snapshot of the World's Water Quality: Towards a global assessment. United Nations Environment Programme, Nairobi, Kenya. 162pp

Cover Design

Audrey Ringler UNEP

Design & Layout

Audrey Ringler UNEP & **Ogarit Uhlmann** F&U confirm, Leipzig

Credits

Cover image front: iStock photo ID:23936695 **Bartosz Hadyniak**

Cover image back: iStock photo ID:49215240 **Ilona Budzbon**

This report in the form of PDF can be viewed and downloaded at *http://www.unep.org/publications/*

Acknowledgements

UNEP Coordination

Hartwig Kremer, **Norberto Fernandez** (until 2013), **Patrick Mmayi, Keith Alverson & Thomas Chiramba** (until 2015)

Project Coordination

Dietrich Borchardt & **Ilona Bärlund** Department of Aquatic Ecosystem Analysis, Helmholtz Centre for Environmental Research – UFZ

Chief Editor

Joseph Alcamo Center for Environmental Systems Research (CESR), University of Kassel

Scientific Editors

Joseph Alcamo Center for Environmental Systems Research (CESR), University of Kassel **& Dietrich Borchardt** Department of Aquatic Ecosystem Analysis, Helmholtz Centre for Environmental Research – UFZ

Technical Editor

Ilona Bärlund Department of Aquatic Ecosystem Analysis, Helmholtz Centre for Environmental Research – UFZ

Contributing Authors

Chapter 1

Deborah V. Chapman UNEP GEMS/Water Capacity Development Centre, Environmental Research Institute, University College Cork

Joseph Alcamo Center for Environmental Systems Research (CESR), University of Kassel

Chapter 2

Jeanette Völker, Désirée Dietrich & Dietrich Borchardt Department Aquatic Ecosystem Analysis, Helmholtz Centre for Environmental Research – UFZ

Philipp Saile UNEP GEMS/Water Data Centre, International Centre for Water Resources and Global Change, German Federal Institute of Hydrology

Angela Lausch Department Computational Landscape Ecology, Helmholtz Centre for Environmental Research – UFZ

Thomas Heege EOMAP GmbH & Co.KG

Chapter 3

Martina Flörke, Joseph Alcamo, Marcus Malsy, Klara Reder, Gabriel Fink & Julia Fink Center for Environmental Systems Research (CESR), University of Kassel

Jeanette Völker & Dietrich Borchardt Department of Aquatic Ecosystem Analysis, Helmholtz Centre for Environmental Research – UFZ

Karsten Rinke Department of Lake Research, Helmholtz Centre for Environmental Research – UFZ

Chapter 4

Ilona Bärlund Department Aquatic Ecosystem Analysis, Helmholtz Centre for Environmental Research – UFZ

Marcelo Pires da Costa National Water Agency of Brazil Upper Tietê

Prasad Modak Environmental Management Centre LLP, Mumbai Godavari

Adelina M. Mensah & Chris Gordon Institute for Environment and Sanitation Studies (IESS), University of Ghana Volta

Mukand S. Babel Water Engineering and Management, Asian Institute of Technology **& Pinida Leelapanang Kamphaengthong** Water Quality Management Bureau, Pollution Control Department, Ministry of Natural Resources and Environment, Thailand Chao Phraya

Chris Dickens International Water Management Institute (IWMI), South Africa Vaal

Seifeddine Jomaa Department of Aquatic Ecosystem Analysis, Helmholtz Centre for Environmental Research – UFZ **Sihem Benabdallah** Centre de Recherches et des Technologies des Eaux, Tunisia **& Khalifa Riahi** Laboratory of Chemistry and Water Quality, Department of Management and Environment, High Institute of Rural Engineering and Equipment, University of Jendouba Medjerda

Gregor Ollesch Elbe River Basin Community, Magdeburg Elbe

Dennis Swaney Department of Ecology & Evolutionary Biology, Cornell University **Karin Limburg** Department of Environmental and Forest Biology, State University of New York College of Environmental Science & Forestry **& Kevin Farrar** NY State Department of Environmental Conservation, Division of Environmental Remediation Hudson

Joseph Alcamo Center for Environmental Systems Research (CESR), University of Kassel

Chapter 5

Dietrich Borchardt Department Aquatic Ecosystem Analysis, Helmholtz Centre for Environmental Research – UFZ

Chris Gordon & Adelina M. Mensah Institute for Environment and Sanitation Studies, University of Ghana

Jesper Goodley Dannisøe DHI

Roland A. Müller Department of Environmental Biotechnology, Helmholtz Centre for Environmental Research – UFZ

Joseph Alcamo Center for Environmental Systems Research (CESR), University of Kassel

Advisory Committee, participants of two Advisory Committee meetings March 2014 & January 2015

AC1 & AC2

Mukand Babel Asian Institute of Technology

Peter Koefoed Bjørnsen UNEP-DHI, Denmark

Deborah V. Chapman UNEP GEMS/Water Capacity Development Centre, Environmental Research Institute, University College Cork

Johannes Cullmann UNESCO-IHP and German Federal Institute of Hydrology

Chris Dickens International Water Management Institute (IWMI), South Africa

Javier Mateo Sagasta Divina International Water Management Institute (IWMI) Sri Lanka

Sarantuyaa Zandaryaa UNESCO Division of Water Science

AC2 only

Marcelo Pires da Costa National Water Agency of Brazil

Sara Marjani Zadeh FAO

AC1 only

Fengting Li Tongji University, People's Republic of China

Monica Perreira Do Amaral Porto University of São Paulo

Julius Wellens-Mensah WMO Department of Climate and Water

Hua Xie International Food Policy Research Institute USA

Reviewers

Salif Diop Université CAD Dakar, Sénégal **Alan Jenkins** NERC-CEH, UK **Mick Wilson** UNEP Chief Scientist's Office **Hong Yang** Eawag, Switzerland

Sara Marjani Zadeh FAO **Javier Mateo Sagasta Divina** IWMI **Kate Medlicott** WHO **Cecilia Scharp** UNICEF

Funding

The Government of Norway and the Government Canada through its Environment Canada as well as UN Water are gratefully acknowledged for providing the necessary funding that made the production of this publication *"A Snapshot of the World's Water Quality: Towards a global assessment"* possible.

For more information see: *www.wwqa-documentation.info*

Executive Summary

Main messages

- Good water quality, together with an adequate quantity of water, are necessary for achieving the Sustainable Development Goals for health, food security and water security. Therefore it is of concern that water pollution has worsened since the 1990s in the majority of rivers in Latin America, Africa and Asia.
- It is important that actions to protect and restore water quality are linked to efforts to achieve the Sustainable Development Goals and the Post 2015 Development Agenda.
- Severe pathogen pollution already affects around one-third of all river stretches in Latin America, Africa and Asia. In addition to the health risk of drinking contaminated water, many people are also at risk of disease by coming into contact with polluted surface waters for bathing, clothes cleaning and other household activities. The number of rural people at risk in this way may range into the hundreds of millions on these continents.
- Severe organic pollution already affects around one-seventh of all river stretches in Latin America, Africa and Asia and is of concern to the state of the freshwater fishery and therefore to food security and livelihoods.
- Severe and moderate salinity pollution affects around one-tenth of all river stretches in Latin America, Africa and Asia and is of concern because it impairs the use of river water for irrigation, industry and other uses.
- The immediate cause of increasing water pollution is the growth in wastewater loadings to rivers and lakes. Ultimate causes are population growth, increased economic activity, intensification and expansion of agriculture, and increased sewerage hook-ups with no or a low level of treatment.
- Among the groups most vulnerable to water quality deterioration in developing countries are women because of their frequent usage of surface water for household activities, children because of their play activities in local surface waters and because they often have the task of collecting water for the household, low income rural people who consume fish as an important source of protein, and low income fishers and fishery workers who rely on the freshwater fishery for their livelihood.
- Although water pollution is serious and getting worse in Latin America, Africa, and Asia, the majority of rivers on these three continents are still in good condition, and there are great opportunities for short-cutting further pollution and restoring the rivers that are polluted. A mix of management and technical options supported by good governance will be needed for these tasks.
- A wide range of management and technical options are available to developing countries for water pollution control. Many of these options were not available or used by developed countries when confronted with similarly deteriorating water quality decades ago.
- Monitoring and assessment of water quality are essential for understanding the intensity and scope of the global water quality challenge. Yet the coverage of data in many parts of the world is inadequate for this purpose. For example, the density of water quality measuring stations in Africa is one hundred times lower than the density used elsewhere in the world for monitoring. An urgent task is therefore to expand the collection, distribution, and analysis of water quality data through the international GEMS/Water Programme and other activities. Hot spot areas of water pollution identified in this report can be used to set priorities for data collection.

People and ecosystems require both an adequate *quantity* of water as well as an adequate *quality* of water. Therefore, it is urgent to assess where *water quality is inadequate or under threat* and to incorporate the need for good water quality into the concept of water security. This report focuses on water quality and its relation to development objectives such as health, food security and water security. To make this connection, the report reviews important water quality problems in surface waters including pathogen pollution, organic pollution, salinity pollution and eutrophication. The focus is on three continents: Latin America, Africa, and Asia.

Enhancing water security has been an international priority for the last several years. Through Millennium Development Goals and other efforts, the international community has given priority to the quantity side of water security by expanding the access of people to a safe water supply. Indeed, delivering an adequate amount of water to people, to industry, and to agriculture is, and should remain, a high international priority.

But another dimension of water security is becoming increasingly important – ensuring that freshwaters have an adequate quality of water. This is of concern because the water quality of the world's rivers and lakes is going through important changes. The growing priority being given to water quality is reflected in various targets in the Sustainable Development Goals.

Water quality has markedly improved in many developed countries, although some problems persist. Meanwhile, in developing countries the tendency is towards increasing water pollution as urban populations grow, material consumption increases and untreated wastewater volumes expand. But the actual situation of water quality in freshwater ecosystems in much of the world can only be conjectured because of the lack of basic information. Therefore, an assessment is urgently needed to identify the scope and scale of the "global water quality challenge". This pre-study aims to provide some of the building blocks for a full-scale world water quality assessment that can be scaled up to a full assessment. It also presents a preliminary estimate of the water quality situation of freshwater ecosystems in the world, with an accent on rivers and lakes on three continents.

Water pollution has worsened since the 1990s in the majority of rivers in Latin America, Africa, and Asia.[1]

Changes between 1990 and 2010 in key parameters in rivers reflecting pathogen pollution (faecal coliform bacteria), organic pollution (biochemical oxygen demand; BOD), and salinity pollution (total dissolved solids; TDS) have been estimated. The level of pathogen pollution and organic pollution worsened in more than 50 per cent of river stretches on all three continents, while salinity pollution worsened in nearly a third[2]. The worsening is of particular concern in a subset of these river stretches where water pollution has increased to a severe level, or was already at a severe level in 1990 and had worsened by 2010.

Severe pathogen pollution[3] already affects around one-third of all river stretches in Latin America, Africa and Asia. The number of rural people at risk to health by coming into contact with polluted surface waters may range into the hundreds of millions on these continents. Among the most vulnerable groups are women and children.

Severe pathogen pollution (where monthly in-stream concentrations of faecal coliform bacteria are > 1000 cfu/100ml[4]) is estimated to affect around a quarter of Latin American river stretches, around 10 to 25 per cent of African river stretches and about a third to one-half of Asian river stretches. Hence, of the three continents, the extent of pathogen pollution appears to be greatest in Asia. Taking into account the fraction of rural population that is likely to come into contact with surface waters[5] it is estimated that approximately 8 to 25 million people are at risk in Latin America, 32 to 164 million in Africa and 31 to 134 million in Asia. The wide range of these estimates shows that there are still many unknowns about the actual risk, but also that the numbers of people at risk are likely to be very large. These estimates do not include farmers exposed to contaminated irrigation water, nor people living in cities.

---

[1]In this report the following UNEP "Global Environmental Outlook" sub-regions are used to define "Latin America", "Africa", and "Asia":
Latin America = Central America, South America, Caribbean;
Africa = Central Africa, Eastern Africa, Northern Africa, Southern Africa, Western Africa, Western Indian Ocean;
Asia = Central Asia, North East Asia, South Asia, South East Asia, West Asia region (Arabian Peninsula, Mashriq)

[2]In this summary, rounded figures are used for the results of analyses. It is appropriate to present rounded results considering the uncertainties of the underlying estimates. The main text presents these underlying estimates.
This includes people coming into contact with rivers that have a severe level of pathogen pollution (x > 1000 cfu/100ml)

[3]A severe level of pathogen pollution is defined in Footnote 5. Such water bodies are likely to have a level of pathogens as indicated by a high level of faecal coliform bacteria, implying that people coming into contact with these waters are exposed to a high health risk.

[4]The standard units of fecal coliform concentrations are "colony-forming units" (cfu) per 100 ml of water sample.

[5]This includes people coming into contact with rivers that have a severe level of pathogen pollution (x > 1000 cfu/100ml)

At particular risk are women because of their frequent usage of water from rivers and lakes for cleaning clothes and collecting water for cooking and drinking in the household, and children because of their play activities in local surface waters and also because they often have the task of collecting water for the household.

It is worth noting that concentrations of faecal coliform bacteria have increased between 1990 and 2010 in almost two-thirds of all rivers in Latin America, Africa and Asia. The river stretches with an "increasing trend of particular concern"[6] amount to about one-quarter of the total kilometres of rivers in these continents where faecal coliform bacteria levels increased to a severe level, or were at a severe level in 1990 and worsened by 2010. These can be considered hot spot areas.

A large fraction of the increase is due to the expansion of sewer systems that discharge wastewater untreated into surface waters. On one hand, by taking the wastewater away from populated areas, the sewers have reduced the health risk posed by unsafe sanitation practices on land. On the other hand, by dumping sewage untreated into surface waters, they have transferred the health risk from the land to surface waters. It was estimated that if sewers had not been built, fecal coliform loadings into African rivers in 2010 might have been 23 per cent smaller. The solution, however, is not to build fewer sewers, but to treat the wastewater they collect.

Severe organic pollution already affects around one out of every seven kilometres of all river stretches in Latin America, Africa and Asia. The high level of organic pollution and its increasing trend is of concern to the state of the freshwater fishery and therefore to food security and livelihoods. Groups affected by organic pollution include poor rural people that rely on freshwater fish as a main source of protein in their diet and low income fishers and workers who rely on the freshwater fishery for their livelihood.

Organic pollution is caused by the release of large quantities of decomposable organic compounds into surface water bodies. The breakdown of these compounds often leads to a serious reduction in the dissolved oxygen resources of a river relied upon by fish and other aquatic fauna.

Fish from inland waters make up an important part of the protein in the diet of people in developing countries. Globally, the inland fishery is the sixth most important source of animal protein, but in some developing countries the catch of inland fish accounts for more than 50 per cent of the animal protein produced within that country.

Inland capture fisheries are also an important source of livelihood in developing countries. Inland fisheries in developing countries provide employment for 21 million fishers and 38.5 million related jobs. Almost all of these were in small scale fisheries, occupied by mostly low income people, with over half of the total workforce being women. It is therefore disquieting that at least 10% of all measurements from Latin America, Africa, and Asia show levels of concern for at least three out of five water quality parameters of particular importance to the health of fisheries.

In 2010, severe organic pollution (where monthly in-stream concentrations of BOD are > 8 mg/l) is estimated to affect up to around one-tenth of Latin American river stretches, up to about one-seventh of African river stretches, and up to about one-sixth of Asian river stretches.

It is also of concern that organic pollution (as indicated by increasing river concentrations of BOD) has increased between 1990 and 2010 in almost two-thirds of all rivers in Latin America, Africa and Asia. A subset of these river stretches with an "increasing trend of particular concern" amount to about one-tenth of the total kilometres of rivers in these continents where BOD levels increased to a severe level, or were at a severe level in 1990 and worsened by 2010. These can be considered hot spot areas.

Severe and moderate salinity pollution already affects around one-tenth of all river stretches in Latin America, Africa and Asia and is of concern because high salinity levels impair the use of river water for irrigation, industry and other uses. Groups affected by salinity pollution include poor farmers that rely on surface waters as a source of irrigation water for their small holdings.

"Salinity pollution" occurs when the concentration of dissolved salts and other substances in rivers and lakes is high enough to interfere with the use of these waters. Although almost all rivers have some salt content because of weathering of soils and rock in their drainage basin, society has greatly increased these levels by discharging salt-laden irrigation return flows, domestic wastewater and runoff from mines into rivers.

[6]"Increasing trend of particular concern" in this report means a pollution level that increased into the severe pollution category in 2008–2010, or was already in the severe pollution category in 1990-1992 and further increased in concentration by 2008–2010.

Saline pollution is less widespread than pathogen or organic pollution on the continents studied. Nevertheless, moderate and severe salinity pollution together (i.e., where monthly in-stream concentrations of TDS are > 450 mg/l) affect one out of every twenty kilometres of rivers in Latin America, up to about one-tenth of river stretches in Africa, and up to about one-seventh of river stretches in Asia. River water in the moderate pollution category is partly restricted for use in irrigation, and cannot be used for some industrial applications without further purification. Particularly affected may be poor farmers who rely on surface waters as a supply of irrigation water for their small holdings.

Salinity pollution has increased between 1990 and 2010 in almost one-third of all rivers on the three continents. A subset of these river stretches (a few percent of all river reaches) have an "increasing trend of particular concern" in which TDS levels increased to a severe level, or were at a severe level in 1990 and worsened by 2010.

Anthropogenic loads of nutrients to major lakes are significant and may cause or further advance eutrophication of these lakes. The trends of these loads are different in different parts of the world.

Eutrophication is the over-fertilisation of lakes and other water bodies which leads to a disruption of their natural processes. Lake eutrophication is usually caused by anthropogenic loads of phosphorus, but loads of nitrogen can also play a role. More than half of the total phosphorus loads in 23 out of 25 major lakes[7] worldwide are from anthropogenic sources. In addition, most of the major lakes in Latin America and Africa have increasing loads. By comparison, loads are decreasing in North America and Europe because of effective phosphorus-reducing measures.

The immediate cause of increasing water pollution is the growth in wastewater loadings to rivers and lakes. The most important current sources of pollution vary from pollutant to pollutant. Ultimate causes of growing water pollution are population growth, increased economic activity, intensification and expansion of agriculture, and increased sewerage with no or low level of treatment.

Collecting wastewater in sewers reduces the direct contact of people with wastes and pathogens and in this way is an important strategy for protecting public health. However, building sewers has also concentrated the discharge of pollutants into surface waters and shifted the location of health risk to people.

The largest source of pathogen pollution (loadings of faecal coliform bacteria) in Latin America is domestic wastewater from sewers, for Africa it is non-sewered domestic waste, and for Asia it is domestic wastewater from sewers followed closely by non-sewered domestic waste.

The largest source of organic pollution (BOD loadings) in Latin America is domestic wastewater from sewers, for Africa it is non-sewered domestic waste, and for Asia it is wastewater from the industrial sector.

The largest anthropogenic source of salinity pollution (loadings of TDS) in Latin America is industry, and in Africa and Asia it is irrigated agriculture.

Important sources of anthropogenic phosphorus to major lakes in Latin America are livestock wastes and inorganic fertiliser, in Africa livestock wastes, in Asia and Europe domestic wastewater, livestock wastes and inorganic fertiliser, and in North America inorganic fertiliser.

Although water pollution is serious and getting worse in Latin America, Africa, and Asia, the majority of rivers on these three continents are still in good condition, and there are great opportunities for short-cutting further pollution and restoring the rivers that need to be restored.

In previous points the focus was on the extensive reaches of rivers where water quality is poor and further deteriorating. But the other side of the coin is that many stretches of rivers *are not yet polluted:*

- About one half to two-thirds of all river reaches (in Latin America, Africa and Asia) have a *low* level of pathogen pollution
- More than three-quarters have a *low* level of organic pollution, and
- About nine-tenths have *low* salinity pollution.

It is still possible to prevent these clean river reaches from becoming heavily polluted. It is also possible to begin restoring the river reaches that are already polluted. Many actions can be taken to avoid the increase in pollution and restore polluted freshwaters:

[7]In this report "major world lakes" means the five largest lakes in terms of lake surface area in each of five UNEP "Global Environmental Outlook" regions (Africa, Asia, Europe, Latin America, and North America).

1. *Monitoring* – More understanding is needed about the intensity and scope of the global water quality challenge. For this understanding, it is urgent to expand the monitoring of water quality, especially in developing countries, and especially at the international level through GEMS/Water.
2. *Assessments* – Comprehensive national and international assessments of the global water quality challenge are needed. These assessments are needed for pointing the way to priority locations and actions for dealing with water pollution.
3. *New and old management and technical options* – Developing countries have an opportunity to not only employ traditional wastewater treatment, but also to draw on many more new management and technical options for managing water quality including nature-based solutions.
4. *Setting up effective institutions* – An essential part of managing water quality is setting up institutions that promote action and overcome barriers to controlling water pollution.

These ideas are elaborated in the following points:

What can be done: I. Monitoring

Comprehensive assessments of global water quality are not possible because of the poor coverage of water quality data of surface waters in GEMStat, the only global water quality data base.

GEMStat has a very low density of stations as compared to typical minimum densities of around 1.5 to 4 stations per 10,000 km^2 of river basin area in the USA and Europe. In GEMStat, 71 out of the 110 river basins with data have a density of 0.5 stations per 10,000 km² or less.

The average density for the Latin American continent is 0.3 stations per 10,000 km², for Africa 0.02 stations[8] per 10,000 km², and for Asia 0.08 stations per 10,000 km² for the time period between 1990 and 2010.

The highest priority is to expand the temporal and spatial coverage of monitoring stations rather than increase the number of parameters collected at existing stations. Considering the high costs of monitoring it is important to set priorities on which data-deficient rivers should be monitored first. The hot spot areas identified in this report can be used as input in deciding where to expand monitoring efforts.

The reasons for poor data coverage are political, institutional, and technical. But there are many alternatives for improving coverage of water quality data.

One alternative for improving coverage is to make use of remote sensing data. Current data sets cover key water quality variables for lakes, and in the near future data will become available for rivers. An advantage of remote sensing is the extensive spatial and temporal coverage of the data; disadvantages include the limited number of variables that can be measured and the processing of raw data that is required.

Other options for improving coverage of water quality data are: (i) increasing efforts to incorporate national and regional data into existing databases, (ii) establishing national freshwater monitoring working groups to work with their counterparts in other countries on sharing and using water quality data, (iii) retrieving data through citizen science projects. Citizen science has the added advantage of engaging a wider public in cleaning up water pollution.

Data collection efforts should also strive to make these data widely available and retrievable through a digital platform such as "UNEP Live". Data should also be made widely available in connection with the monitoring and implementation of the Sustainable Development Goals.

What can be done: II. Assessment

A full scale World Water Quality Assessment is needed to assess the state of knowledge about all critical aspects of water quality, to make linkages between water quality and other Post 2015 Development issues such as health and food security, and to identify priority areas for study and actions.

The assessment should be:

- Multi-level – with global coverage linked to national assessments and thematic assessments.
- Transparent and participatory – involving a wide range of stakeholders and scientists.

[8]Dryland areas are not included in the continental area.

The assessment should include:

- Objectives and themes that are jointly selected by the policy and science communities.
- An analysis of policy options for protecting and restoring water quality.
- Wide access to results by making them available on new digital platforms (e.g. "UNEP Live").
- The assessment should also be used as an opportunity to increase the technical capacity of developing countries and their access to the latest scientific results.

What can be done: III. Management and Technical Options

There are many options available to developing countries for avoiding the water quality deterioration of their rivers and lakes. Many of these options were not available or used by developed countries when confronted with similarly deteriorating water quality decades ago.

The main technical options are:

(i) *Pollution prevention* in which the source of water pollution is avoided before it becomes a problem.

(ii) *Treatment of polluted water* which is the traditional approach to reducing the loading of pollutants before they are discharged into surface waters.

(iii) *The safe use of wastewater* recycling it for irrigation and other uses.

(iv) *"Nature-based solutions" involving the restoration and protection of ecosystems*, such as re-establishing woodlands in catchments in order to reduce erosion and sediment loadings to rivers or restoring wetlands to remove pollutants from urban or agricultural runoff.

Under these headings there are many new ideas that were not available to developed countries when they first confronted similarly deteriorating water quality three or more decades ago. Among these new ideas are: *cleaner production in industry*, *constructed wetlands*, *zero effluent discharges*, and *payment for ecosystem services of forested headwaters.*

Different technical strategies will be needed to control the diverse types of water pollution and sources of pollution. It is worthwhile to try and cluster these strategies into packages that can be applied to many different river basins.

On one hand, it was noted above that the main sources of pollution differ between the different kinds of water pollution. This means that a "one size fits all" option will not work to solve the global water quality challenge. On the other hand, similar water quality challenges are occurring around the world even if the locations and situations are very different. Therefore, it may be possible to develop different packages of technical options that can be used in many different river basins to deal with similar problems.

What can be done: IV. Governance and Institutions

Case studies of different river basins pointed out the importance of good governance and effective institutions for managing water quality.

It was found that important barriers to coping with water pollution problems include:

- Fragmentation of authority within a river basin,
- Lack of technical capacity, and
- Lack of awareness on behalf of the public about the causes of water pollution.

To overcome these and other barriers, experience from the case studies showed that a public education campaign is a good first measure for gaining support for water pollution control. Another lesson is that an *Action Plan*, agreed upon by all the main actors in a river basin, is a key step in restoring rivers and lakes. Yet another key institutional step for international rivers is to set up a *collaborative body* such as the international commissions on the Elbe and Volta rivers for developing and carrying out an action plan. In the case of the Elbe, it was also shown that a wide-reaching national institution (the Elbe River Basin Community) can provide a valuable platform for gaining the cooperation of all critical *national* actors within a river basin.

Coping with the global water quality challenge is closely connected to many other priorities of society such as food security and health. Therefore, actions to protect water quality should be embedded in the larger concept of sustainability, and be part of efforts to achieve the new Sustainable Development Goals.

The case studies showed that the challenge of protecting water quality is intertwined with many other tasks of society – providing food, developing the economy, and providing safe sanitation. Therefore, over the coming years it will be very important to link goals for water quality with other goals of the Post 2015 Agenda and the new Sustainable Development Goals.