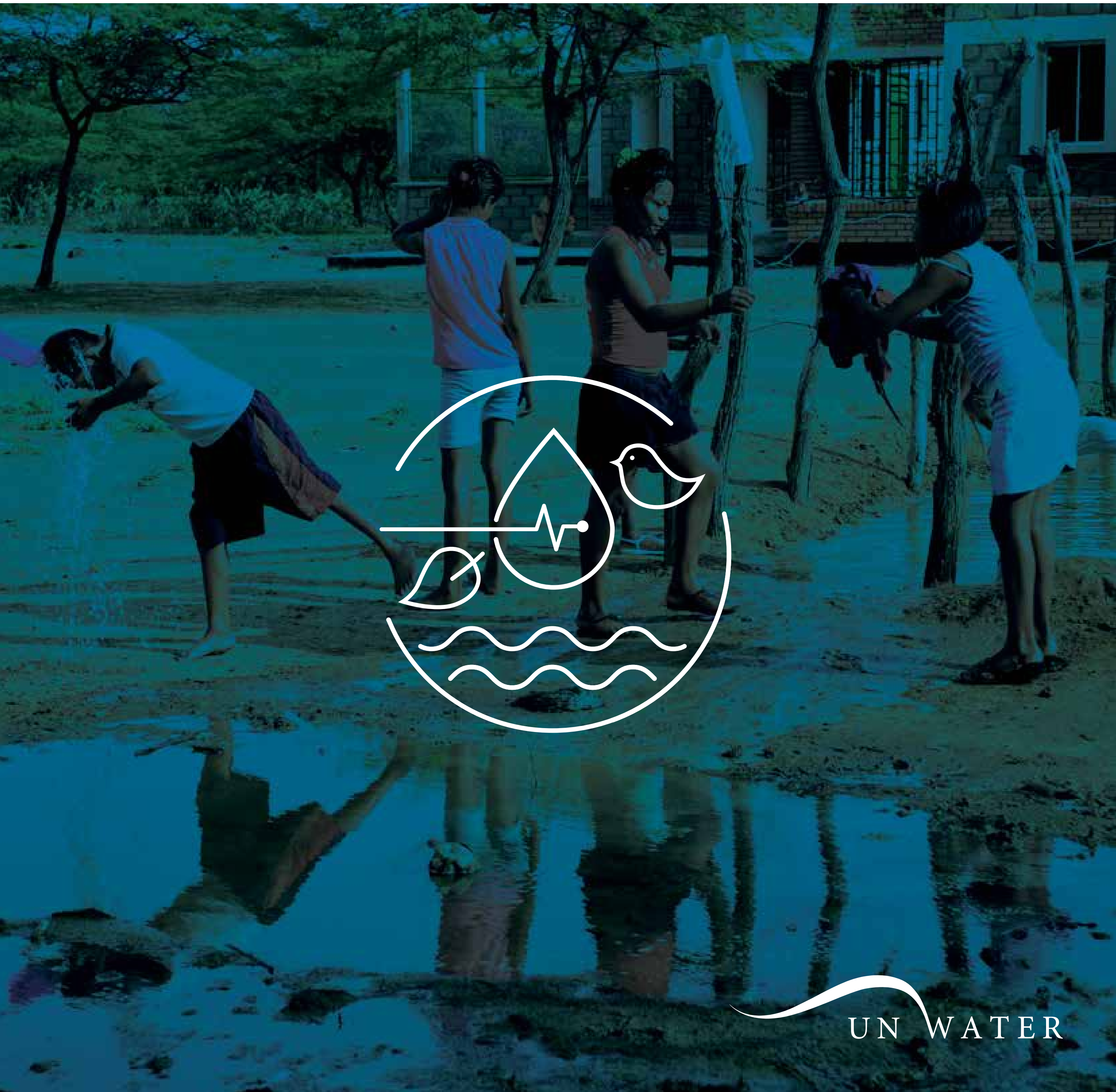
Towards a Worldwide Assessment of Freshwater Quality

A UN-Water Analytical Brief



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Content

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Key Messages

More data are urgently needed in order to better understand the world's water quality challenge, which is affecting key freshwater ecosystem services such as drinking water, health, biodiversity and food security. A worldwide water quality assessment would provide policymakers and other stakeholders with information they need in order to make informed decisions to address this issue.

Executive Summary

water is **health**

The world is facing a water quality challenge. Serious and increasing pollution of fresh water in both developing and developed countries poses a growing risk to public health, food security, biodiversity and other ecosystem services. Pollution is strongly linked to economic development – with population growth and the expansion of agriculture, industry and energy production all in turn producing wastewater, much of which goes into surface and groundwater bodies uncontrolled or untreated. Despite recent preliminary assessments of the current worldwide water quality situation, the magnitude of the challenge is still unknown. Better information is required on where the issues lie and what is needed to effectively and efficiently take action to protect and improve water quality.

Poor data availability makes it challenging to develop a global water quality assessment, despite the urgent need to better understand the state and drivers of water quality around the world.

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This Analytical Brief provides information about past assessments, outlines the challenge but also provides a plan for a world water quality assessment, which, if undertaken, would provide decision makers with the information they need to address this challenge. The Analytical Brief also explores the strong linkages between water quality and the Sustainable Development Goals (SDGs). SDG 6, "Ensure availability and sustainable management of water and sanitation for all," includes a specific target (6.3) dedicated to water quality. Central questions include: 'how can the water quality target be achieved?'; 'How will worsening water pollution affect SDGs for health, food security, and biodiversity, among others?'; Or, conversely, 'how can actions to protect and enhance water quality help meet other SDGs?'.

The global assessment outlined in this Analytical Brief is proposed to have four major interconnected components: (1) a *baseline assessment of the state of water quality worldwide* to provide an understanding of the relative condition of surface water bodies in different parts of the world and to identify hot spot areas of water pollution; (2) a *scenario analysis of water quality trends* to identify the factors worsening water quality, such as economic growth and climate change; (3) an *analysis of mitigation options* to identify the different options available to developing and developed countries for avoiding further water quality deterioration or for improving water quality; and (4) an *analysis of governance approaches* that are most appropriate and effective in different locations to encourage good water quality management including the monitoring and reporting of SDG 6.

The outputs of such a global assessment would include new and important data, policy-relevant information and co-designed knowledge for policymakers and stakeholders at different levels to cope with the global water quality challenge (e. g. UN institutions, national governments, river basin authorities, and citizens).

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1. Introduction

1.1. Background and purpose of the Analytical Brief

Due to increased societal attention and political action, pollution reduction, cleaner production and changing consumption patterns over the last decades have seen an observable improvement in the quality of many of the developed world's surface water bodies and to a lesser extent groundwater (EEA 2015). But particularly in developing countries, such as those in Latin America, Africa, and Asia, economic and demographic changes have been triggering an increase in water pollution, posing a risk to public health, food security, biodiversity, and other ecosystem services. Major pollutants include nutrients, pathogens, heavy metals, organic pollutants and micro-pollutants found in wastes and wastewater from humans and economic activities such as agriculture, industry, mining, and other sectors such as pharmacy. Indeed untreated wastewater is one of the biggest sources of water pollution. By some estimates, up to 90% of wastewater globally gets dumped into water bodies untreated (UNEP, UN-Habitat 2010). Data and baselines, however, are noticeably absent.

The Snapshot of the World's Water Quality (UNEP 2016), though only intended as a rapid preliminary assessment, already reveals a worrying level of pathogenic and organic pollution as well as salinity in many rivers in Latin America, Africa and Asia.

Many of these drivers, trends, challenges and impacts were outlined in previous UN-Water publications, including a water quality Policy Brief (UN-Water 2011) and another Analytical Brief on Wastewater Management (UN-Water 2015). "Emerging contaminants" present new water quality challenges, as new materials and chemicals, and harmful micro-pollutants from pharmaceuticals, for example, can harm the health of both humans and ecosystems, including freshwater biodiversity (Millennium Ecosystem Assessment, 2005).[i] Eutrophication, the over-fertilization of water bodies, is of particular concern for freshwater bodies and their ability to provide ecosystem services, including drinking water and support to biodiversity (OECD 2012).[ii] Meanwhile, climate change has taken on global dimensions and affects water quality in various ways (e. g. increasing pollution from city surfaces, and altering the dilution capacities of rivers). All together, these amount to a new "global water quality challenge" which requires a response from the international community as well as decision-makers at all levels.

Some aspects of the global water quality challenge were articulated in a recent report, *Snapshot of the World's Water Quality*, published by UN Environment (UNEP) with the support of UN-Water (UNEP, 2016). The *Snapshot* presents a rapid, preliminary assessment of the current water quality situation, in particular in rivers and in developing countries. It also proposes a methodological framework for further assessment, and identifies major data and knowledge gaps. Main messages of the report are given in Box 2-1. Among its important findings are the sources, extent, and impacts of salinity, organic and pathogenic pollution.

To confront the challenge portrayed in the *Snapshot* report and elsewhere we urgently need to understand the many dimensions of the worldwide water quality situation. But the latest full global water quality assessment was published back in 1989 (Meybeck et al. 1989) and since then the world has greatly changed. There are now over 2 billion more people in the world, and in developing regions many more sewers and industrial waste discharges with inadequate wastewater treatment have been built up. As a result, between 1990 and 2010 pathogen and organic pollution has increased in about two-thirds of all river reaches in Latin America, Africa and Asia (UNEP 2016).

While the *Snapshot* report provided a useful overview of the water quality situation it was only a first step in an urgently needed detailed assessment. A detailed assessment calls for better data; an expanded number of water quality parameters; an outlook of future water quality under climate change and especially socio-economic changes; an analysis of the link between water pollution and its threat to public health, inland fisheries, and other ecosystem services; and a review of the technical and governance options for addressing water pollution.

The purpose of this Analytical Brief is therefore to present the need and a potential outline for a full worldwide water quality assessment. It presents:

- The background and context of the proposed assessment, especially how it relates to the 2030 Agenda for Sustainable Development.
- The current challenges for a global assessment and how these could be overcome (e.g. improving capacity and resources for water quality monitoring at the national level)
- The guiding questions and objectives of the assessment
- A strategic approach to the assessment
- A sketch of the four components of the assessment, together with advantages and disadvantages of different methodological approaches within these components

Taken as a whole, the report gives a "road-map" for initiating a worldwide water quality assessment.

[i] Three Millennium Ecosystem Assessment (2005) publications looking at contemporary state and trends, wetlands, and natural assets, respectively, note that biodiversity of freshwater ecosystems has been degraded more than any other ecosystem, including tropical rainforests. For example, in the United States and Europe, more than 40% of freshwater fish species are in imminent danger of extinction.

[ii] The deterioration in water quality resulting from eutrophication is estimated to have already reduced biodiversity in rivers, lakes and wetlands by about one-third globally, with the largest losses in China, Europe, Japan, South Asia and Southern Africa (OECD, 2012)

Box 1-1. Main messages from the Snapshot of the World's Water Quality (modified from UNEP 2016)

• Good water quality, together with an adequate quantity of water, are necessary for achieving the Sustainable Development Goals for health (SDG 3), food security (SDG 2), water security (SDG 6) and ecosystems (SDG 14 and 15). 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 other efforts to achieve the Sustainable Development Goals and the 2030 Agenda for Sustainable Development.

• Severe pathogen pollution (largely from the expansion of sewer systems that discharge wastewater untreated into surface water systems), including pathogenic microorganisms such as faecal coliform bacteria, 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, washing clothes 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 (including plant nutrients from agricultural run-off such as nitrogen or phosphorus) already affects around one-seventh of all river stretches in Latin America, Africa and Asia and is of concern to freshwater fisheries and therefore to food security and livelihoods.

• Severe and moderate salinity pollution (from irrigation, domestic wastewater and runoff of mines into rivers) 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 connections with no or low levels 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 water 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 river networks on these three continents are still in good condition. This is because major pollution sources are spatially concentrated rather than evenly distributed. Therefore, “smart” spatial planning and management offer great opportunities for shortcutting 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 for water pollution control. Many of these options are available and used in developed countries today.

• Monitoring and evaluation of water quality are essential for understanding the intensity and scope of the global water quality challenge. Yet the availability 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 (UNEP 2016). An urgent task, therefore, is to expand the collection, sharing, and analysis of water quality data, especially by strengthening national capacity for water quality monitoring, through, for example, the GEMS/Water Programme, FAO AQUASTAT and other international activities. Hot spot areas of water pollution identified in the Snapshot report can be used to set priorities for data collection.

1.2. Assessment questions

An assessment of the worldwide water quality situation is needed to address many different important questions. Here is a set of core questions:

- What is the water quality situation in different parts of the world considering the targets for water quality in the Sustainable Development Goals (SDGs)?
- What are the linkages between water quality and SDGs for health, food security, and biodiversity, among others?
- What is the water quality situation in different parts of the world with regards to different water quality parameters?
- What is the trend of water quality, and what are the main drivers of these trends?
- For a particular location, what is the relationship between pressures, impacts, and responses to water quality degradation?
- What are the various alternatives for technical measures or management strategies to protect good water quality or reduce water pollution?
- What is the role of governance in maintaining or restoring water quality?

1.3. Main components of a global assessment

To deal with the above questions, an assessment structure with four major interacting components is proposed (Figure 2-1):

1. A **baseline assessment of the state of water quality** to provide an understanding of the relative condition of water quality in different parts of the world and to pinpoint hot spot areas requiring particular attention. This baseline assessment would fill in the gaps in knowledge identified in the *Snapshot* report.
2. A **scenario analysis of water quality trends** to identify dynamic trends over the next 10 to 50 years in water quality, in particular for locations of worsening water quality and of particular importance for social, economic or ecological reasons. To ascertain the impact of climate change and other changing driving forces on water quality.
3. An assessment and **analysis of mitigation options** available to developing and developed countries for avoiding further water quality deterioration or for improving the water quality of surface and groundwater. This would involve examining both technical measures and management approaches.
4. An assessment and **analysis of governance approaches** to identify the options for governance – legal, economic, behavioral, technological, or cognitive – that are most appropriate and effective at different locations to encourage good water quality management.

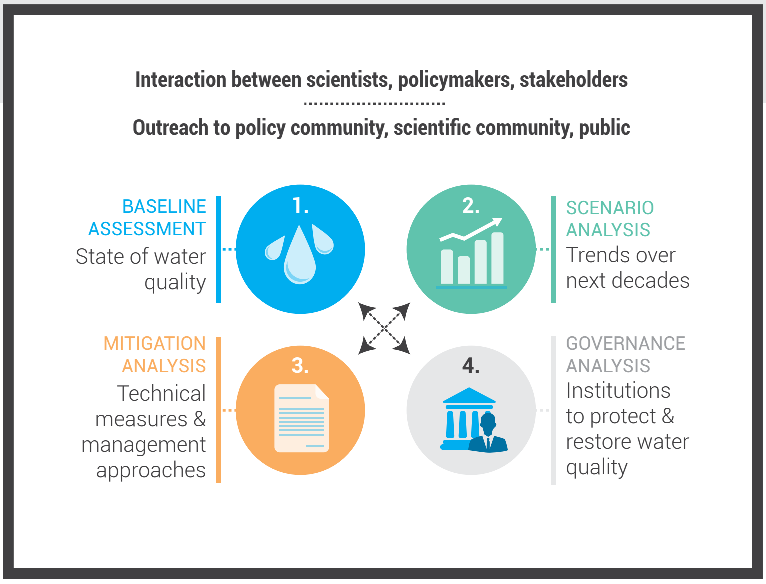
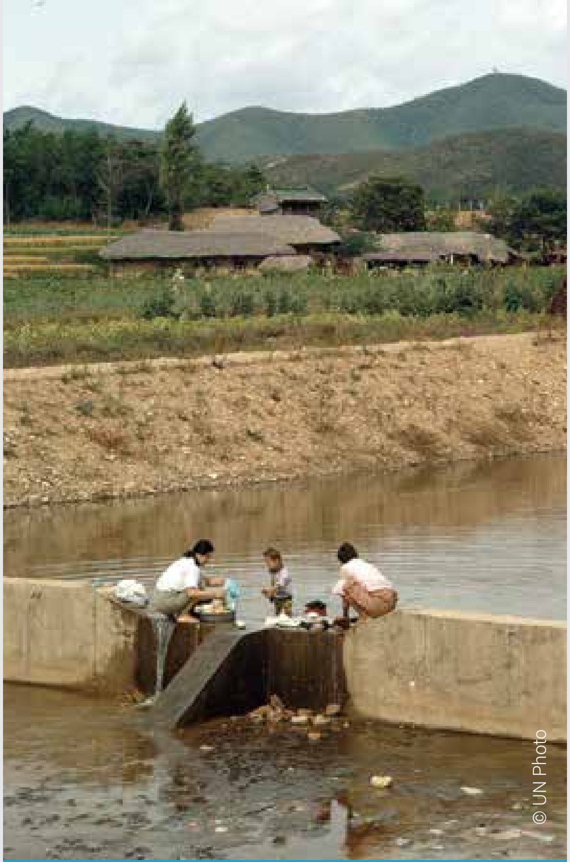


Figure 1-1. Components of a worldwide water quality assessment.
The arrows symbolize that information and knowledge would be exchanged between all four components of the assessment.
Snapshot of the World's Water Quality (UNEP, 2016).



2. Water quality across the 2030 Agenda for Sustainable Development

The Sustainable Development Goals (SDGs) in the 2030 Agenda for Sustainable Development are especially significant because they represent an international agreement on the priorities for sustainable development for the next decade and a half. The commitments UN Member States have made to Agenda 2030 carry important implications for monitoring and reporting, including for targets related to water quality and wastewater management.[iii] Accordingly, they are likely to have a decisive influence on all aspects of international and national policies regarding the environment, including those concerned with water quality. It is sensible, then, to make the SDGs a major cross-cutting theme of a worldwide water quality assessment. Under the "water and sanitation goal" of the SDGs (SDG 6, "Ensure availability and sustainable management of water and sanitation for all"), Target 6.3 says explicitly:

6 CLEAN WATER AND SANITATION

"By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally"[iv]

Water quality is a prerequisite for sustainable water and sanitation in Sustainable Development Goal (SDG) 6, but it is also essential for many other SDGs such as those related to health, food security and biodiversity, among others.

In connection with this target, two indicators have been proposed for global monitoring and reporting purposes: indicator 6.3.1, "Percentage of wastewater safely treated," and 6.3.2, "Percentage of bodies of water with good ambient water quality."[v] A worldwide water quality assessment would help countries in their monitoring and reporting efforts towards this target and should therefore assess if/how the aim to "improve water quality" by 2030 will be achieved under various scenarios mentioned in the target such as by reducing pollution and minimizing the release of hazardous chemicals. Such an assessment should include the two global SDG indicators adopted by the international community to track the SDG water quality target, including the one related to wastewater. It should, for example, explore how the

[iii] *For more information on integrated water-related monitoring and reporting in the Agenda 2030, see http://www.unwater.org/gemi/en/.*

[iv] *See the 2030 Agenda for Sustainable Development, https://sustainabledevelopment.un.org/post2015/transformingourworld.*

[v] *See report of the Inter-agency and Expert Group on SDG Indicators (IAEG-SDGs) to the 47th session of the UN Statistical Commission, March 2016: http://unstats.un.org/unsd/statcom/47th-session/documents/2016-2-SDGs-Rev1-E.pdf.*

wastewater target can be achieved under various technical options, identify barriers to the adoption of these options, and how these barriers can be overcome under various governance options.

In addition to the specific SDG target for water quality, it is clear that the future state of water quality will also have a profound influence on other SDGs. A recent UN-Water publication, "Water and sanitation interlinkages across the 2030 Agenda for Sustainable Development," documents the reinforcing interlinkages between SDG 6, including the water quality target 6.3, and the other SDGs (UN-Water 2016). For water quality, these include connections to targets related to increasing access to public services (SDGs 1 and 11), ending hunger (SDG 2), improving health (SDG 3), increasing access to energy (SDG 7), promoting sustainable tourism and industrialization (SDGs 8 and 9), and reducing marine pollution (SDG 14). Figure 3-1 depicts some of these connections.

A useful guide for countries to understand the various water quality requirements and regulations for different uses, such as domestic, recreational, industry and agriculture, see the recently published *Compendium of Water Quality Frameworks: Which Water for Which Use?* (UN-Water 2015).

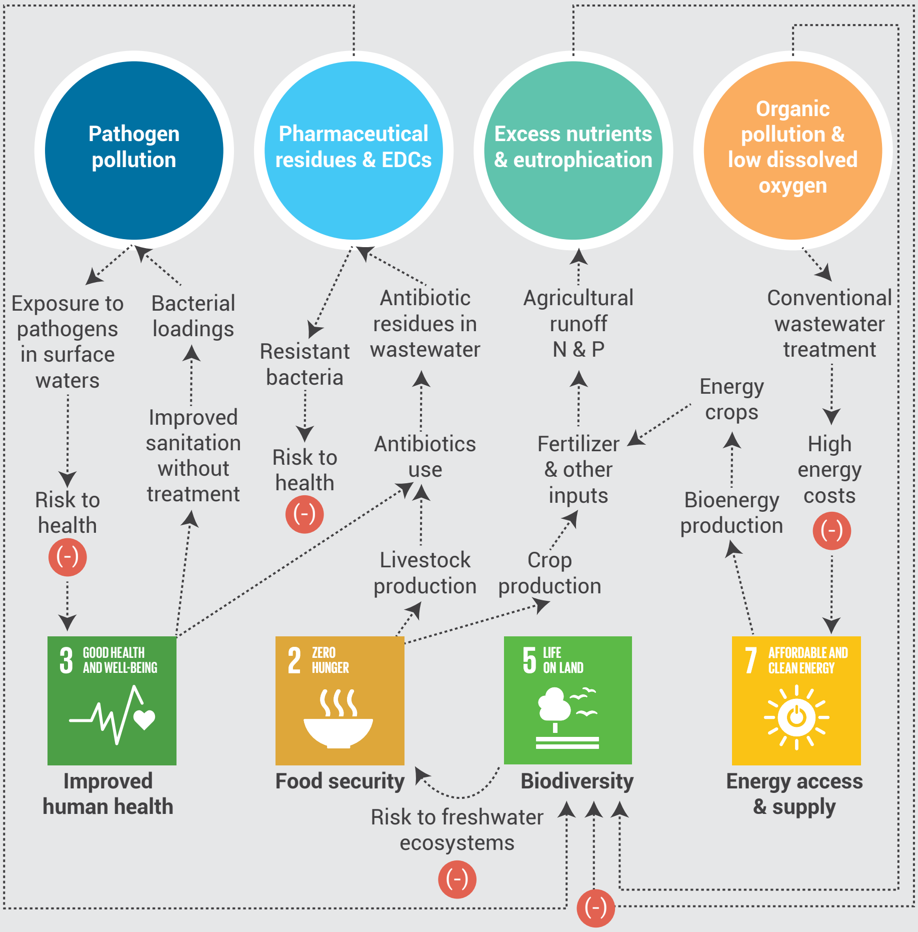


Figure 2-1. Linkages of water quality with selected Sustainable Development Goals. From UNEP 2016, Snapshot.

2.1. Water quality and public health

Targets 3.9 and 12.4 of the SDGs specifically aim to reduce water pollutants and other pollutants in order to minimize their impacts on human health and the environment:

> 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination
>
> 12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

Poor water quality can have many different impacts on human health. The WHO/UNICEF Joint Monitoring Programme for Drinking Water and Sanitation (JMP) monitors access to safely managed water and sanitation services under the SDGs (wssinfo.org) and WHO publishes periodic updates to the global burden of disease for diarrhea and other water and sanitation related diseases such as soil transmitted helminths and schistosomiasis attributable to unsafe drinking water, lack of sanitation and poor hygiene (WHO 2016). The *Snapshot* report assessed the risk of water-borne diseases from contamination of faecal coliforms in locations where people come into direct contact with polluted water in lakes, rivers and other surface water bodies. Particularly affected are the poor in rural areas of developing countries who often use surface water for washing clothes, for retrieving cooking water, or for bathing. In places where contaminated surface or groundwater or wastewater are used for irrigation purposes, additional risks exist for both humans and ecosystems. These include, for humans, health risks due to exposure to a variety of pollutants such as salts, metals, metalloids, pathogens, residual drugs, organic compounds, endocrine disruptor compounds and active residues of personal care products that may be found in the water, and is a risk for those who grow, sell, or prepare produce. Risks to the environment involve pollution of soil and groundwater, including salinization, which in turn has implications for biological diversity (FAO, 2011). In particular, nutrients such as phosphorus and nitrogen, commonly found in fertilizers, contribute to the deterioration in water quality due to eutrophication, a major cause of reduction in biodiversity worldwide (OECD 2012).

Very preliminary estimates from the *Snapshot* report are that up to 300 million rural people in developing countries may be at particular health risk from contact with polluted waters. A worldwide water quality assessment should assess this important issue and elaborate the following:

- The level of bacterial and other pathogen pollution in rivers and lakes, especially in developing countries. This was done in a preliminary way using model estimates in the *Snapshot* report, but a worldwide assessment needs in-stream measurements to confirm these estimates
- The population at risk of being exposed to contamination of rivers, lakes, and other surface fresh water bodies through bathing, washing clothes, collecting water for household purposes, irrigation, and through other activities which bring people into contact with water. Again, the *Snapshot* report made only very preliminary estimates of this population.
- The amount of hormones, heavy metals, and other harmful substances in rivers and lakes, in both developing and developed countries, and the public health risk posed by the occurrence of these substances.
- The additional costs for drinking water treatment of contaminated surface and groundwater sources.

2.2. Water quality and economic activities, including food production

Food and water are inextricably linked. It is well known that the majority of the world's fresh water withdrawn from rivers and aquifers (nearly 70 per cent) is used for agriculture. Demand for food is only set to increase with rising population growth and urbanization, which in turn puts additional pressure on freshwater resources – the Food and Agriculture Organization estimates that food production must increase by 70 per cent by 2050 to meet demand (FAO 2009). Yet the importance of the quality of the water used for irrigation is less understood. Acknowledging this is crucial as more and more farmers, especially in the urban and peri-urban areas of arid or semi-arid regions, rely on using untreated wastewater to grow their food, which can have implications for human and ecosystem health (IWMI 2004).

Most studies of future global food requirements assume that a substantial fraction of world food production will come from irrigated cropping areas (Mauser et al. 2015). It is also expected that supplemental irrigation will be used more often in rainfed cropping areas because of increasing air temperatures and possibly lower precipitation rates related to climate change (Mauser et al. 2015).

In the *Snapshot* report important first steps were made in estimating current river salinity levels and their suitability as a source for irrigation in developing countries. It was estimated that salinity levels in about one-tenth of all river reaches in Latin America, Africa, and Asia are already at or above the level of "increasing restriction" for use in irrigation. No assessment, however, was made of the quality of groundwater available for irrigation.

A worldwide water quality assessment should build on this important information and compare water quality from rivers, lakes and groundwater to the local and regional needs for irrigation water. Based on these data reliable estimates should be made of the locations where irrigated food production could be limited because of poor water quality.

Aquaculture and freshwater fisheries are an important source of animal protein in the diet of people, especially in developing countries. Globally, inland fishery is the sixth most important source of animal protein, and in some low income countries such as Bangladesh and Cambodia, more than half the animal protein produced comes from freshwater fishery (FAO 2009). Yet the degradation of biodiversity of freshwater ecosystems has particularly dire consequences for fish: it has been estimated that already more than 40% of freshwater fish species in the United States and Europe were in imminent danger of extinction (Millennium Ecosystem Assessment 2005).

Therefore the sustainable production of freshwater fisheries is particularly relevant for achieving food security (SDG 2), especially Targets 2.1 and 2.2:

> 2.1 "By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations ...", and
> 2.2 "By 2030, end all forms of malnutrition ...."

It is clear that achieving SDG 2 will depend to an extent on sustaining productive freshwater fisheries. But this production is now threatened by many factors including overfishing, destruction of habitat, and water pollution. One type of pollution particularly threatening to freshwater fisheries is organic pollution which occurs when an excess of easily biodegradable wastes, for example nutrients such as phosphorus, nitrogen and potassium from agricultural run-off, enter rivers and lakes. Eutrophication, the over-fertilization of water bodies, is of particular concern as decreased oxygen levels lowers their ability to provide ecosystem services, including drinking water and support

to biodiversity (OECD, 2012). As noted previously, the *Snapshot* report estimated that one in seven kilometers of river stretches in Latin America, Africa and Asia are affected by severe organic pollution, and that this type of pollution has increased between 1990 and 2010 in around two-thirds of all river stretches on these continents. The report also presented a methodology for a worldwide assessment that can be used for linking pollution levels with risk to freshwater fisheries and food security (Box 3-1).

In a worldwide water quality assessment the following analyses are needed:

- Estimates of organic pollution, eutrophication, endocrine disruptors, and toxic pollutants in worldwide rivers and lakes that pose a possible threat to freshwater fisheries.
- Estimates of the dependence of human populations on fish consumption and a matching of water quality indicators in rivers and lakes.
- Estimates of locations where freshwater fisheries are under greatest risk from water pollution, especially in developing countries which most depend on them for food.
- Estimates of the economic value of inland fisheries and their contribution to employment should also be compiled.

With regards to industrial water use, the *Snapshot* report provided new information on the salinity contamination of rivers in developing countries which is a valuable indicator of the suitability of water for industrial and energy production uses. Building on this information, a worldwide water quality assessment should estimate locations where salinity and other water contaminants may limit the use of rivers and lakes for industrial water supply.

With regards to recreational use, many countries are concerned about protecting their rivers and lakes as important sources for recreational boating, bathing, fishing, and other free time activities. In a worldwide water quality assessment, estimates should be made of where poor water quality may interfere with the use of fresh waters for recreation. Not only bacterial contamination should be taken into account, but also the presence of trace toxic substances. This should also be linked to the activities regarding pathogen pollution referred to in Section 3.1.

Box 2-1. A methodology for assessing the linkage between water quality and the status of the inland fishery. Modified from UNEP (2016).

The following paragraphs present initial ideas for a methodology for identifying regions where inland fisheries are vulnerable to water quality deterioration.

Firstly, preliminary indicators of inland fisheries and water quality are developed (see figure below). Secondly, these indicators are used to evaluate how and where water quality degradation influences the production of inland fisheries and their relation to food security on a global scale.

Examples of possible inland fishery indicators are "national dietary intake" and "national fish catch trends" and examples of possible water quality indicators are "level of concern of water quality parameters" and "trends of BOD instream concentrations". The Snapshot report computed preliminary estimates of these indicators using data from FAO (Fishery and Aquaculture Global Statistics – FishstatJ), and the World Bank country population data. "National dietary intake of inland fisheries" was calculated as the total reported inland fisheries catch per country divided by country population. The computed data were then categorized into "higher" or "lower" intake based on the calculation of the 75th percentile of countries reporting inland fisheries yields.

The indicator "national inland fisheries catch trend" was computed by comparing average decadal yields from 1990–1999 with 2000–2010. Decadal averages were used because of large year-to-year fluctuations. These trend data give only a very rough approximation of the status of inland fishery resources because, among other reasons, they do not explain the specific reasons for an increasing or decreasing trend.

In a worldwide water quality assessment, many more indicators of fish consumption and fishery status need to be considered, for example, the development level of a country and the occurrence of over-fishing. Furthermore, indicators need to be developed at the river basin or finer scale so that they can be related to water quality and other river conditions.

2.3. Water quality, biodiversity, and other ecosystem services

Besides its relevance to public health and food security, good water quality is also needed to ensure the health of freshwater ecosystems, the adequacy of water supply for industry, and the availability of surface waters for recreation.

From the *biodiversity* perspective, Target 15.1 of the SDGs sets out a target for protecting freshwater ecosystems by specifying that states should...

"... ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services ...".

Accordingly, a worldwide water quality assessment should estimate where poor water quality poses a risk to freshwater ecosystems and their services in all countries. These estimates should be coordinated with the studies of the impact of water pollution on public health described in Section 2.1.

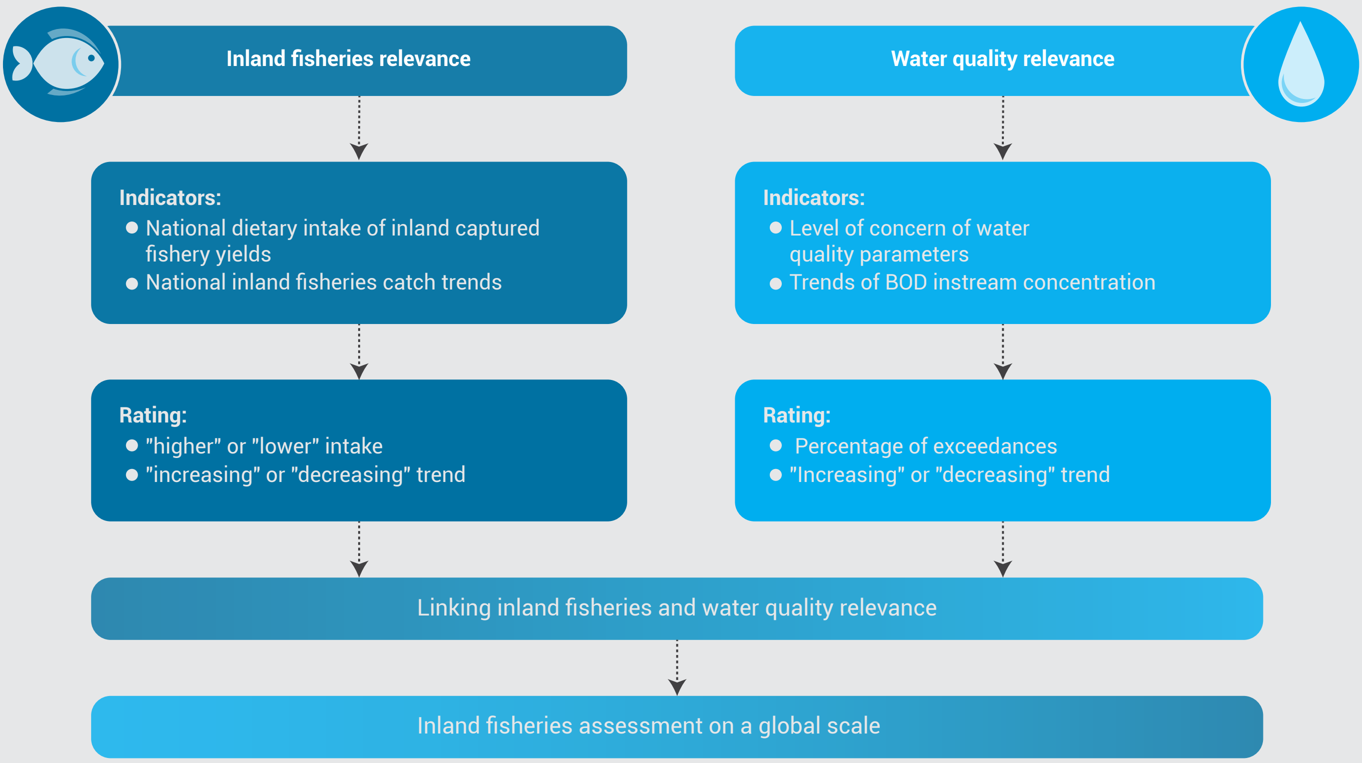


Figure 2-2 Proposed scheme for assessing the status of inland fisheries with regard to water quality degradation, with example indicators

3. Objectives and strategic approach of assessment

3.1. Proposed objectives of the global assessment

Considering the particularly important context of the SDGs, the goals of a worldwide water quality assessment are proposed to be:

- To review the state of water quality of the world's freshwater system, especially with respect to the Sustainable Development goals for public health, food security, biodiversity, and societal uses of fresh water;
- To identify the freshwater areas most under threat from water pollution, now and over the coming decades;
- To identify technical options that can be replicated, transferred and scaled-up to effectively protect or restore water quality in countries of contrasting conditions;
- To raise awareness of water quality degradation and the importance of halting and reversing this trend for local and national sustainable development;
- To increase the capacity of developing countries to better assess the situation and effectively protect or restore the water quality of their surface and ground waters.
- To increase water quality monitoring and reporting capacity.

The worldwide water quality assessment would be a global environmental assessment in that it will be a science-based process that encourages the full engagement of the scientific community.

3.2. Overall output of the assessment

Such an Assessment could be a key step in helping policymakers, stakeholders, and scientists better understand the extent and type of water quality problems around the world. It would ...

- be a major awareness-raising exercise and increase capacity around the world to cope with the water quality challenge;
- provide information about policy options for protecting or restoring water quality so that water systems can better provide services to society such of food production and water supply;
- provide critical input for the 2030 Agenda for Sustainable Development, for monitoring and reporting on the SDGs and for other important international activities.

3.3. Policymaker and stakeholder engagement

The worldwide water quality assessment would be a global environmental assessment in that it will be a science-based process that encourages the full engagement of the scientific community. Also consistent with the definition of a global environmental assessment, it will engage the ultimate users of its results – policymakers and stakeholders – during all of its phases, from its planning through to its execution and the distribution of results.

3.4. The DPSIR approach

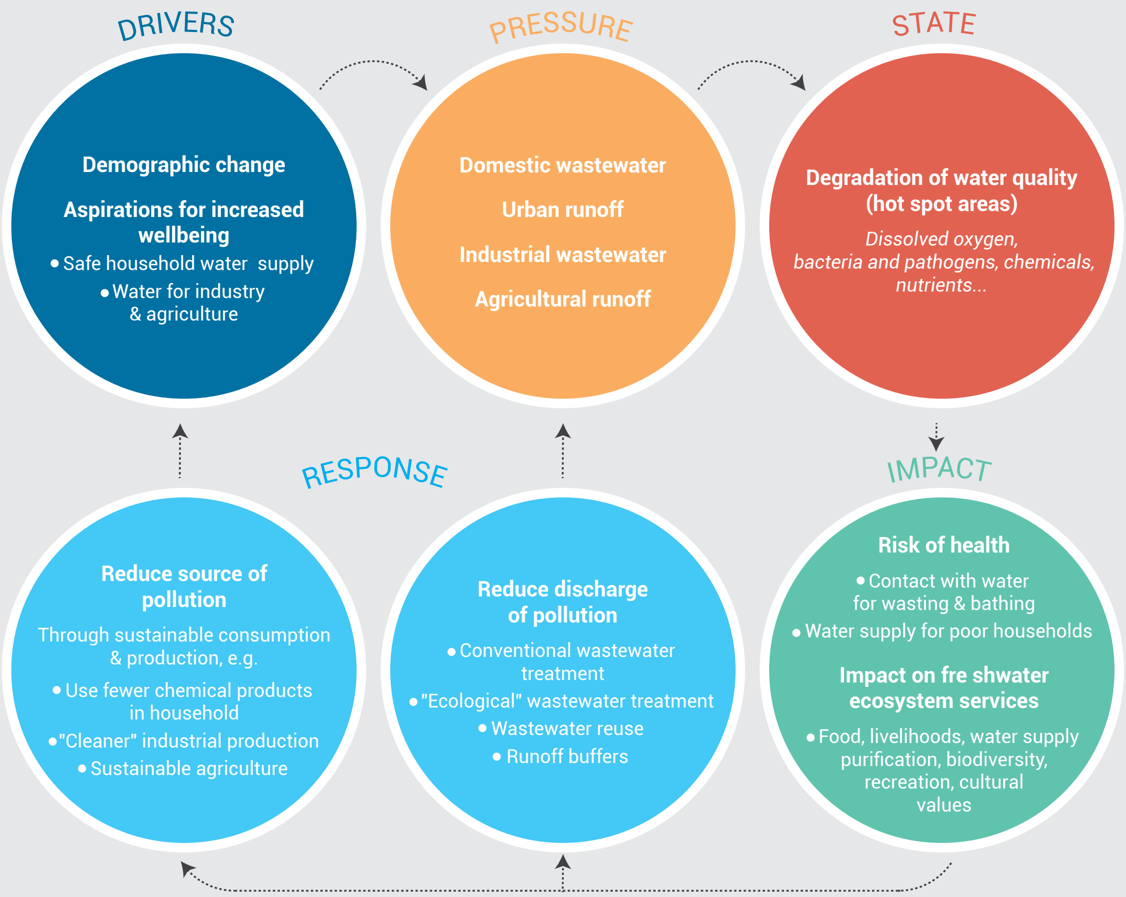
To assess the world water quality situation, it is proposed to use the "DPSIR" conceptual framework (Figure 4-1). This framework divides different aspects of a system into linked "drivers" (D), "pressures" (P), "states" (S), impacts" (I) and "responses" (R). "Drivers" are the underlying factors influencing changes in water quality including changes in population density and distribution. "Pressures" are factors that lead to a direct change in water quality such as increasing domestic wastewater or urban runoff. "State" refers to spatial and temporal aspects of the state of water quality. "Impacts" are the consequences of water pollution, such as on public health and freshwater ecosystem services, while "Response" refers to options that society has to respond to the impacts of water pollution. This framework will be used to structure information in the assessment.

3.5. Two spatial scales

While acknowledging the importance of being able to aggregate data at the national level, it is proposed that an assessment could be carried out on two spatial scales:

The global scale – The special added value of the worldwide water quality assessment will be its global/international perspective. It will provide an overview of the state and trends of water quality in different regions and identify particular "hot spot" areas of water pollution. The global analyses of mitigation options and governance options will review best practice experience and innovative approaches from around the world with the aim to present the latest international thinking on mitigation and governance with regards to managing water pollution.

The river basin scale – A disadvantage of the global scale is the risk of presenting results that are too aggregated or abstract for use by many policymakers and stakeholders. For that reason, the global scale analysis will be carried out in parallel to an analysis of several case study river basins in different world regions. The analysis and comparison of river basins in different parts of the world will provide fine grain information (intensity of water pollution, sources of water pollution, experience with technical options and governance) not available from the global analysis. Data from river basins will also provide a "ground-truthing" of the global analysis. An additional advantage is that it will engage a wider network of experts and stakeholders from around the world in the assessment.



The *Snapshot* report was a test case in assessing water quality at two different spatial two scales – analyses were carried out for three continents and for eight case study river basins. It was found that results at these two scales complimented each other well. For example, the continental analysis was useful for assessing the spatial extent of water quality problems, while the case studies yielded many findings on the governance aspects of managing water quality.

Figure 3-1 The DPSIR framework proposed for the worldwide water quality assessment. From UNEP 2016, Snapshot.

4. Component 1: Baseline assessment

Although priority will be given to surface water, data on groundwater quality will also be compiled.

4.1. Objectives

The first major component of the proposed worldwide water quality assessment could be a baseline assessment of water quality in surface water bodies around the world (Figure 2-1), which could feed into integrated global monitoring for water and sanitation in Agenda 2030 (see www.unwater.org/gemi). Although priority will be given to surface water, data on groundwater quality will also be compiled. The objectives of the baseline assessment are:

- To assess the relative condition of freshwater systems in different parts of the world.
- To identify hot spot areas with regards to water pollution that should be given special attention.
- To link levels of water pollution with SDG-related issues such as health, food security and biodiversity (See Section 3).
- To identify the main pressures and drivers of high water pollution levels at different locations.

The output of this part of the assessment would be coherent databases, useful data products, maps and tables showing the level of water quality according to different parameters and the relative level of water pollution. These data will be presented for at least a ten year period. An explicit linkage would be made between water quality levels and the SDGs for health (risk of contact with contaminated surface water), food security (state of inland fisheries, and quality of potential irrigation water supply), biodiversity (state of inland fisheries and other freshwater ecosystem indicators), and other ecosystem services (quality of water supply for industry).

The baseline data from this component could be used as a starting point for the scenarios in Component 2 (Scenario Analysis), inform the SDG baseline for target 6.3.2 on ambient water quality, to evaluate appropriate mitigation measures in Component 3 (Mitigation Analysis), and governance approaches in Component 4 (Governance Analysis).

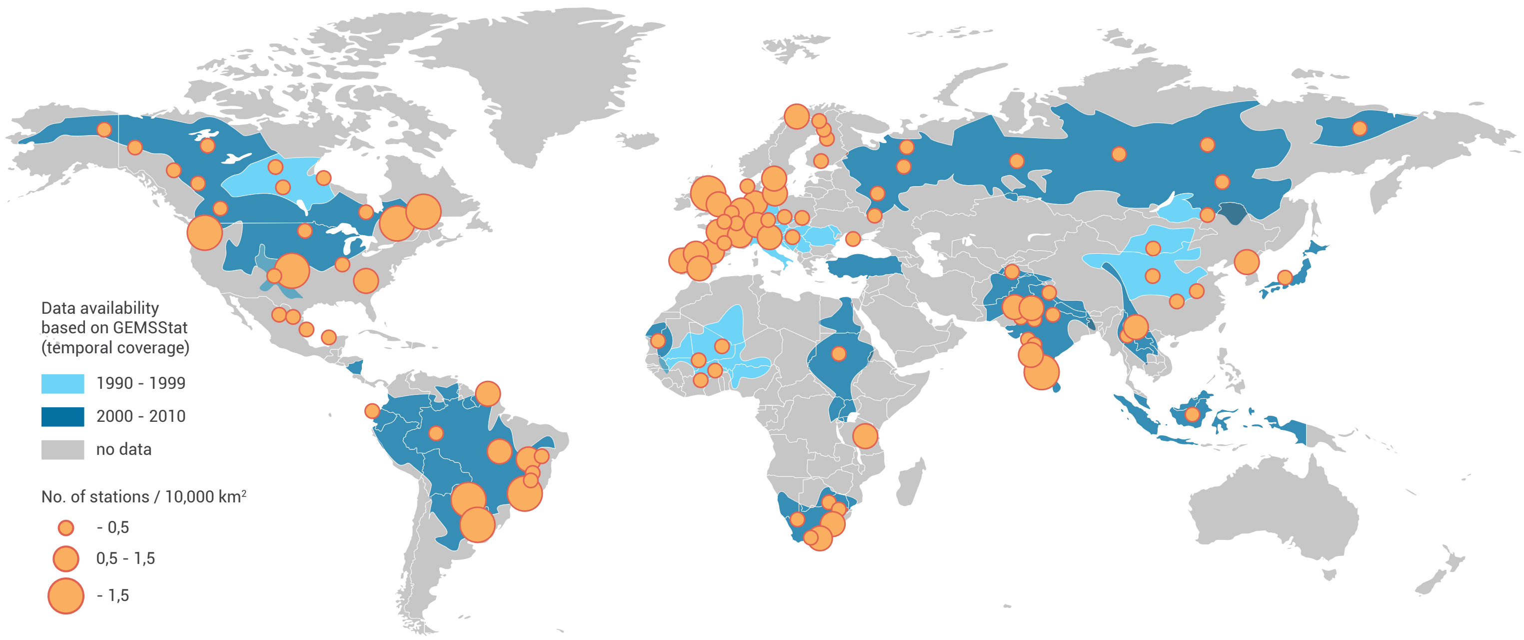


Figure 4-1. Temporal coverage (grey shading) and station density (size of circles) of GEMStat data. From UNEP (2016). Original data source GEMStat (2014).

The *Snapshot* report confirmed that "data are essential for developing, monitoring and evaluating water resources management strategies" and made important first steps in understanding baseline water quality by analysing existing GEMS/Water and other data. It also concluded that the GEMStat database of the UN GEMS/Water programme is a suitable platform for assembling global water quality data and it could be linked with other global databases (e. g. AQUASTAT). But it also found that the current data holdings of GEMS/Water are too sparse spatially and temporally for a global assessment. As compared to a typical monitoring programme (EEA 2014) which has around 1.5 to 4 stations per 10,000 km2, the densities of stations in the GEMStat data base (Figure 5-1) are very low: 71 out of the 110 river basins with data have a density of 0.5 stations per 10,000 km² or less, and only 57 countries report data in the time period of 1990 to 2010. The average density for the Latin American continent is 0.3 stations per 10,000 km², for Africa 0.02 stations per 10,000 km², and for Asia 0.08 stations per 10,000 km² during the time period between 1990 and 2010 (UNEP, 2016). A very high priority, therefore, for a worldwide assessment is to acquire enough quality assured data to achieve a satisfactory temporal and spatial coverage. The definition of "satisfactory coverage" will have to be agreed upon by experts at the outset of the assessment, but it is likely to depend on expected spatial and temporal distribution of pollutants, the variation of different hydrological conditions, the intensity of wastewater loadings, and other factors. The hot spot areas of pollution identified in the *Snapshot* report could be used as input in deciding where to expand monitoring efforts.

Because of the *Snapshot*'s limited scope only a small number of parameters were analysed and in a limited geographic area (continents with developing countries). In a worldwide water quality assessment, a much more comprehensive range of water quality parameters serving as core set of indicators in the DPSIR framework should be analysed, with coverage from both developing and developed countries, and including rivers, lakes, and groundwater.

4.2. Approach

What should be the source of data for a comprehensive worldwide baseline assessment? The *Snapshot* report makes the following recommendations:

a) Incorporating existing national and regional monitoring data into current global data sets.

Following technological advancements and legal obligations (such as the EU Water Framework Directive from 2000), an increasing number of countries are providing their monitoring data publicly and online. One best-practice example is the Water Information System of Europe (WISE) established in 2007, which provides a web-portal entry to water related information ranging from inland to marine waters for all EU institutions as well as Member States, national, regional and local administrations, professionals working in the water field from public or private organisations and the general public.

However, these information systems are limited to developed countries and most of these countries have elaborated their own data exchange formats and access methods that complicate transfer of data into GEMStat. In order to promote the interoperability of data internationally, members of the joint WMO/OGC Hydrology Domain Working Group are standardising open data exchange formats and web services such as WaterML2 and Sensor Observation Services. These steps would lay the foundation for a globally distributed water resources information system that can be used in a worldwide baseline assessment. GEMS/Water is not only aiming to support the standardisation process, but also to implement these standardised formats and services at the national and sub-national scale to enhance data flows.

b) Retrieving existing data through a network of national focal points

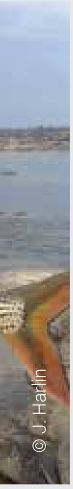
The current GEMS/Water networking and data collection strategy is based on the network of National Focal Points (NFPs), which have the responsibility to facilitate the data flow between GEMS and national states. However, frequent personnel changes at the NFPs hamper communication and data flows. One approach to overcome this barrier is to set up national fresh water monitoring working groups including governmental and scientific representatives who provide a link between national monitoring activities and regional and global assessment programs. On the regional level, newly established GEMS/Water regional hubs (as recently set up in Brazil) can support the maintenance and extension of the Global Monitoring Network and increase the exchange of data.

A complementary activity would be the "Water Solutions Laboratory Network" that is currently established under the "Sustainable Water Future Programme" under "Future Earth", an international research hub driving global environmental change research.

c) Retrieving data from new water quality surveys including citizen science projects

New water quality surveys may be initiated as joint country or basin-wide sampling campaigns (for example, as one-time surveys at selected sensitive locations using standardized water quality methods). These surveys can be combined with data from remote sensing platforms and models (see following sections) to close critical knowledge gaps.

Another consideration is "citizen science", which is the participation and collaboration of private citizens, students or other non-professional individuals and organizations in scientific research. Though not without its downsides, such as the potential for biased reporting and the need to verify data, it is a promising option to retrieve new water quality data. Through citizen science, people share and contribute to sampling and data gathering in data collection programmes. Collaboration in citizen science involves scientists and researchers who develop and coordinate the programme and unpaid volunteers such as students, amateur scientists, or teachers including school networks. Examples of successful initiatives are shown in Box 5-1.



Box 4-1: Examples of citizen science projects on water quality monitoring (Modified from UNEP 2016)

An example of a citizen science project is the "Volunteer Water Quality Monitoring" programme within the National Water Resource Project at the Universities of Wisconsin and Rhode Island in the United States. The goal of this project is to expand and strengthen the capacity of existing extension volunteer monitoring programmes and support the development of new groups. This project includes the training of volunteers in monitoring water quality and developing internet and web-based tools for data management. In 2005, this project engaged 8,600 trained volunteers in monitoring lakes, wells, rivers, estuaries and beaches. In total, the project involves 30 separate collaborative programmes in 30 different states. Local and regional programme coordinators are responsible for the expansion of the programme.

Another example is the development by the Delft University of Technology of new mobile sensing methods for water quality monitoring for use in citizen science projects. Delft is developing "indicator strips" as a convenient and practical way for volunteers to collect water quality data.

A third example is the "World Water Monitoring Challenge" (WWMC) run by Earth Echo International, an environmental education organisation in collaboration with the Water Environment Federation and the International Water Association. As part of this program, volunteers are encouraged to test the quality of their local waterways and share their findings. To facilitate this, the WWMC sells individual and classroom water-testing kits for measuring temperature, acidity (pH), clarity (turbidity) and dissolved oxygen. Each kit contains an informative instruction book and enough reagents to repeat up to 50 tests. The location of stations, data and further information are made accessible to the public on an interactive web site.

d) Deriving data through remote sensing

Another solution to the urgent global data gap is to derive water quality information from remote sensing products. Satellite sensors potentially offer reproducible and globally consistent Earth observation data with a high scientific standard. Therefore, remote sensing can provide data where it is otherwise too expensive to monitor water quality or at locations that are remote. Remote sensing can provide estimates of some water quality parameters at spatial scales and temporal resolutions that exceed those of ground-based monitoring stations by several orders of magnitude. However, despite its many advantages, its inherent limitations should also be kept in mind (Box 5-2). Therefore, remote sensing should be considered only as one part of a multifaceted strategy for monitoring water quality.

Box 4-2. What are the potentials and limitations of remote sensing? (Modified by UNEP 2016).

• Remote sensing has the potential to capture proxies for many of the drivers of water quality, such as population density or agricultural intensity, However, the number of water quality parameters that can be measured by remote sensing is limited to components that influence the optical properties of the water (e.g. chlorophyll and other pigments, organic carbon compounds, suspended solids).

• The application of remote sensing for water quality assessments is further limited by the spatial resolution and spectral information of the satellite missions in place.

• The potential of remote sensing for water quality assessments of lakes and other stagnant waters such as reservoirs is higher than that of rivers.

• Compiling remote sensing data into water quality information requires models that convert spectral signals into water quality parameters. These models either require an independent ground-truthing of remote sensing observations, i.e. calibration, or, as is the case with physical based models, a direct conversion of optical properties into water quality components (e. g. Global Lakes Sentinel Services Project; GLASS 2016; EOMAP 2016).

• Through these methods, water quality parameters such as chlorophyll-a and toxic algae bloom indicators can be derived from remote sensing data with high reliability and unique spatial resolution.

• A prerequisite for successful ground-truthing is the availability of good quality surface water quality measurements with coherent spatial and temporal resolutions. Thus an aquatic sensor network (e. g. Wireless Ad-hoc Sensor Networks for Environmental Monitoring) is required to provide systematically monitored water quality parameters that can be stored in global databases and made accessible for calibration and validation of remote sensing data.

• Future satellite-born remote sensing platforms will have higher spatial resolutions and hyperspectral optical signals and will therefore expand the opportunities for water quality assessments of inland waters.

• A prerequisite for the acceptance of information derived from remote sensing data is the coherence with established monitoring and assessment protocols. The linking and inter-calibration with standardized methodologies needs to be carefully addressed.

e) Filling data gaps through modelling

In the absence of detailed measurements, the *Snapshot* report showed that water quality modelling can be used to fill major gaps in the spatial and temporal patterns of water quality and can provide a detailed geographic overview of the water quality situation. Moreover, models provide an indispensable method to relate levels of water pollution to their underlying causes – including both immediate "pressures" such as wastewater loadings, or underlying "drivers" such as population density (See Section 4.4).

Models will be needed in any case in the *Scenario Analysis* component of the assessment to compute future water quality under climate change and other driving forces (See Section 6). Models will also be used to investigate the water quality impact of different combinations of technical measures and management approaches as part of the *Mitigation Options* component.

Apart from their advantages, models also have the following disadvantages: (1) model calculations are inherently uncertain (e.g. 'garbage in garbage out', data quality, assumptions); (2) models cover some but not all important water quality parameters (lacking process knowledge regarding their environmental behaviour, missing loading or in situ data); and (3) adequate measurements are needed in any event to validate model calculations.

In the *Snapshot* report only one model (Voss et al. 2012) was used for calculations, but in a full assessment an ensemble of models should be used to enhance the robustness of results.

f) Raising awareness on the need for water quality monitoring

As a final note, United Nations agencies and international partners focusing on water quality issues can increase awareness of, and advocate for, the importance of monitoring ambient water quality, and thereby stimulate political and public willingness to fund and implement water quality monitoring programs. Declarations such as Resolution 1/9 of the United Nations Environment Assembly on water quality data exchange should help to further improve data.[iv]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[vi] *UNEA Resolution 1/9 on 27 June 2014 "...emphasizes that the World Water Quality Assessment Report, the water-related sustainable development goals and other assessments on the state of freshwater resources at different geographic scales will require timely, relevant and reliable data and information" and "...underlines the need to further improve the global coverage and consistency of water quality data." Available at http://www.unep.org/unea1/en/.*

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Among the important findings of the Snapshot report was that water pollution and nutrient loading is increasing in a considerable number of rivers and major lakes in developing countries.

5. Component 2: Scenario analysis

5.1. Objectives

Among the important findings of the *Snapshot* report was that water pollution and nutrient loading is increasing in a considerable number of rivers and major lakes in developing countries. For example, it was found that the levels of pathogen and organic pollution increased in almost two-thirds of all river stretches in Latin America, Africa and Asia between 1990 and 2010 (UNEP 2016). With such dynamic changes going on, it is important to go beyond an assessment of *current* water quality, and assess *future* water quality. To increase the robustness of future forecasts, it is recommended to take a *scenario approach*, and estimate a *set of feasible scenarios* of changing water quality under different driving force assumptions.

Hence the second major component of the proposed worldwide water quality assessment is proposed to be a scenario analysis of future pathways of water quality in the freshwater system. The objectives of the scenario analysis are:

- To assess *future* water quality as a result of continuing demographic and economic changes, such as population growth, urbanization, industrial development and consumer patterns, as well as environmental changes, such as in climate, and other driving forces. To determine future hot spot areas of water pollution.
- To estimate the impact of future water pollution on health, food security, biodiversity and other important freshwater ecosystem services related to the achievement of the SDGs.
- To identify the impact of different mitigation and governance scenarios on protecting or improving water quality under different economic scenarios.

The output of this part of the assessment will be scenarios in the form of narratives and model output (e.g. maps, tables, data) that illustrate worldwide trends in water quality over the next decades.
As in the baseline assessment, water quality in these scenarios will also be directly linked to the SDGs for human health (risk of contact with contaminated surface waters), food security (state of inland fisheries,

and quality of potential irrigation water supply), biodiversity (state of inland fisheries and other indicators of the health of freshwater ecosystems), and other ecosystem services (quality of water supply for industry).

Baseline information for the scenarios will come from Component 1 (Baseline Assessment), and input to the mitigation scenarios will come from Components 3 (Mitigation Analysis) and 4 (Governance Analysis).

5.2. Approach

As part of the Scenario Analysis two categories of scenarios could be developed:

> *1) Business-as-usual scenarios.* These scenarios would estimate the future level of water pollution assuming no expansion of current efforts to control sources of water pollution. They provide policymakers and stakeholders with a benchmark for the rivers and lakes at risk from worsening water quality. Climate change and demographic and economic changes would be taken into account in these scenarios.
>
> *2) Policy intervention.* These scenarios would estimate future levels of water pollution considering actions to mitigate water pollution. This type of scenario could be used to provide policymakers and stakeholders with information about the relative effectiveness of different options to control water pollution, and will be based on output from Components 3 and 4 (mitigation options and governance options) of the assessment. The policy interventions to be investigated would be agreed upon with policymakers and other stakeholders. Climate change and demographic and economic changes would also be taken into account in these scenarios.

The scenarios would have two time horizons: (i) 2030 to correspond to the target year of most SDGs, and (ii) 2050 to take into account the medium term effects of climate change and other factors.

The entire scenario exercise could be carried out as an interactive process between experts, policymakers and other stakeholders using the "Story and Simulation approach" (Box 6-1). This approach has been used successfully to develop IPCC scenarios, in the Millennium Ecosystem Assessment, and in other major assessments. It has the advantage of fully engaging policymakers, stakeholders, and scientists in developing the scenarios. It also yields consistent, rich, and informative estimates of the future state of water quality for the given scenarios. The disadvantages are the large technical effort required to develop the scenarios, and the difficulties that arise in reconciling the views of all the actors being involved.

The scenarios themselves would have both *qualitative* and *quantitative* aspects.

- *Qualitative storylines* could be developed by a Scenario Panel made up of policymakers, stakeholders and experts.

- *Quantitative scenarios* could be computed by modelling teams using state-of-the-art water quality models. Models are useful scientific tools for providing credible quantitative estimates of future water quality under changing conditions. As noted earlier, a suite of models (rather than a single model) can be used for calculations in order to increase the robustness of results.

The qualitative and quantitative scenarios would be reviewed and harmonized by the various actors involved in the scenario exercise (Box 6-1)

Box 5-1. A proposed methodology for developing scenarios in the Worldwide Water Quality Assessment

Developing "useful" scenarios of future water quality in the world requires a close cooperation between scientists, policymakers and other stakeholders. To encourage this cooperation, it is proposed to use the "SAS" (Story and Simulation) methodology which has been used in many international scenario-building exercises (Alcamo 2008).

The basic steps of the methodology, as applied to the World Water Quality Assessment, would be as follows:

1. *A scenario panel is organized consisting of policymakers, other stakeholders (e. g. business, civil society, local governments, local users), and experts. Experts include some of the scientists involved in the baseline assessment running in parallel.*

2. *Likewise, a Scenario Team is organized consisting of scientists versed in both qualitative (storylines) and quantitative (modelling) scenario methods.*

3. *At their first meeting, the Scenario Panel works with the Scenario Team and agrees upon the boundary conditions and parameters of the scenarios to be developed, including general demographic and economic conditions, time horizon, spatial coverage and resolution, and other characteristics. At this meeting the first qualitative scenarios ("storylines") are drafted. The Panel also identifies the type of quantitative information, including modelling data needed for the scenarios.*

4. *Based on output from the scenario meeting and other data, the Scenario Team derives a consistent set of quantitative driving forces (e.g. population data) for the model runs. These driving forces are then used by the modelling groups associated with the Scenario Team to compute a first draft of the quantitative scenarios of water quality.*

5. *At the second Scenario Panel meeting, the Panel discusses the first modelling results and revises the storylines accordingly. Further modelling analyses are requested.*

6. *Step 3 is repeated.*

7. *At the third Scenario Panel meeting the Panel reviews the new modelling results, and finalizes the storylines of the scenarios and agrees on the quantitative content of the scenarios, as well as their main messages. (It is possible that further iterations between the Scenario Panel, Scenario Team and modelling groups may be planned.)*

8. *Scenario estimates are documented and distributed in the form of written and visual materials.*

6. Component 3: Analysis of mitigation options

6.1. Objectives

While Components 1 and 2 provide a spatial and temporal overview of water quality in the surface water bodies of the world, Component 3 provides information on how to protect or restore water quality.

The objective of this component would be to identify the different mitigation options available to developing and developed countries for avoiding further water quality deterioration or improving the water quality of surface and groundwaters. These would include both technical measures and management approaches as shown in Table 7-1. Options would be matched to the water quality problems identified in Components 1 and 2 of the assessment.

While Components 1 and 2 provide a spatial and temporal overview of water quality in the surface water bodies of the world, Component 3 provides information on how to protect or restore water quality.

6.2. Approach

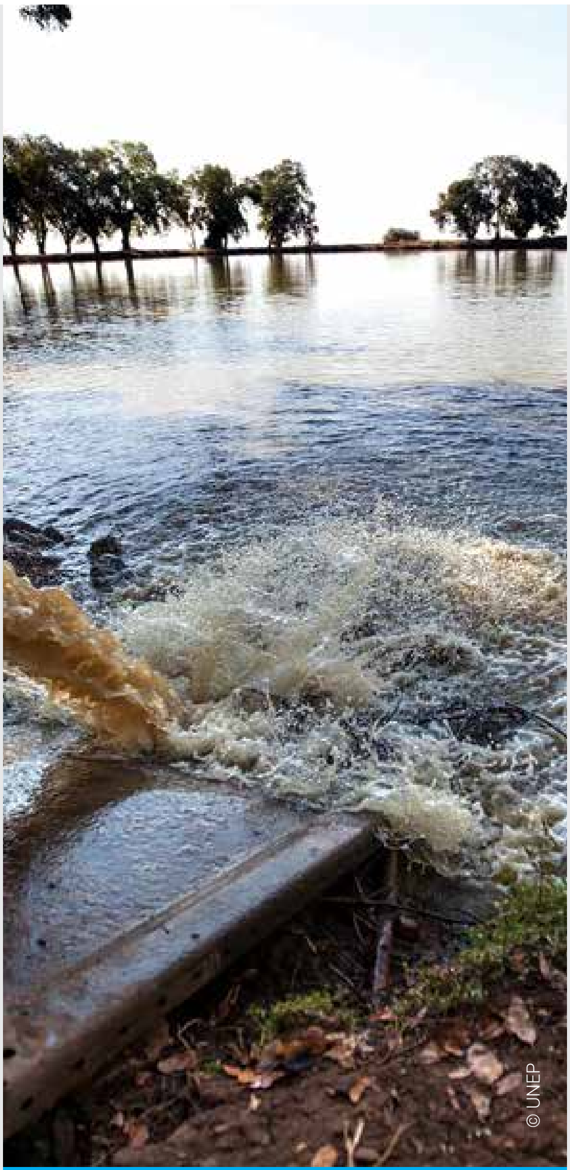
Among the main mitigation options identified in the *Snapshot* report and earlier reports are: (i) pollution prevention, (ii) treatment of polluted water, (iii) the safe use of wastewater and (iv) the restoration and protection of ecosystems (Table 7-1). This categorization or a similar categorization of options would be used in the proposed assessment.

Critical data for a wide range of mitigation options can be compiled and evaluated including the type of water pollutants that are mitigated by a particular option, the technical advantages and disadvantages of different options, and the costs of their implementation. Table 7-1 from the *Snapshot* report gives an example of a simple analysis of these factors for a selection of mitigation options. In the proposed assessment all of these factors could be fully elaborated for each mitigation option and for groups of countries. Both their technical and economic potentials would be evaluated. Apart from established strategies such as traditional wastewater treatment, there are innovative new options included in Table 7-1, such as pollution prevention in industry, constructed wetlands, modular wastewater treatment systems, and conservation and maintenance of forested headwaters or river corridors.

A "one size fits all" option will not work to solve the global water quality challenge. Instead, regionally adapted clusters of measures will be needed to control the diverse types of water pollution and sources of pollution. A full assessment should develop and elaborate packages for sets of measures in a way that addresses priorities in a coherent way and that can be applied to many different river basins.

	MITIGATION OPTION	SOURCE OF POLLUTION	ADVANTAGES/DISADVANTAGES	COSTS/IMPLEMENTATION
POLLUTION PREVENTION	• Increasing water use efficiency • Reduction of wastes – removing hazardous substances and products from production and consumption through legal prohibition, economic incentives, awareness raising • Urban green infrastructures • Increasing effectiveness of fertilizer and pesticide application in agriculture	Industrial and domestic wastewater, urban surface and stormwater runoff, agriculture	Many indirect positive effects (saving resources such as energy and materials etc.); reduces efforts for treatment, green infrastructure in urban areas improves living standards, reduces air pollution and temperature, operation and maintenance have to be secured; implementation may be time consuming; integration in existing processes or infrastructures may be challenging; can be perceived as less reliable than conventional solutions; calls for producer and consumer changes, the use of policy and legal means to bring them about which may be unpopular; direct effects on water quality not always easily detectable; may lower agricultural yield; may require more land in urban areas	Cost effectiveness or return of investment can be high, economic incentives and regulatory frameworks needed, public awareness and participation necessary Can be land intensive (= cost intensive in urban areas)
TREATMENT OF POLLUTED WATER	• Wastewater treatment plants with primary , secondary or tertiary treatment • Constructed wetlands • Enhanced retention in natural floodplains/ wetlands	Industrial and domestic wastewater, urban surface and stormwater runoff, diffuse pollution from agriculture, mining/tailings, landfills	Effective for achieving safe sanitation, perceived as more reliable; operation and maintenance have to be secured; necessary level of treatment and centralized/ decentralized or modular design carefully to be determined; phased implementation may be needed. Constructed wetlands effective for managing diffuse pollution from agriculture, also used for secondary treatment; retention in natural floodplains/wetlands only with regard to biodegradable, non toxic or non accumulative components (e. g. nutrients) or used for improving the quality of treated wastewater	May be cost and energy intensive (investment, operation, maintenance, reinvestment), economic incentives, pricing systems, and further regulatory frameworks needed
SAFE USE OF WASTEWATER	• Use of stormwater • Use of domestic wastewater • Recycling of industrial wastewater (within the same establishment – closed circuit) • Use of industrial wastewater	Industrial and domestic wastewater, urban surface and stormwater runoff	Many indirect positive effects (saving resources, energy and materials etc.); reduces efforts for treatment technologies and thereby minimizing costs; operation and maintenance have to be secured; implementation may be time consuming; integration in existing processes or infrastructures may be challenging; ; calls for producer and consumer changes, the use of policy and legal means to bring them about which may be unpopular	Cost effectiveness can be high; economic incentives and regulatory frameworks needed, pricing systems, public awareness and participation necessary
RESTORATION AND PROTECTION OF ECOSYSTEMS	• Forest conservation in river basins • Conservation and restoration of river corridors • Flow regime management and restoration	Industrial and domestic wastewater, urban surface and stormwater runoff, diffuse pollution from agriculture	Many positive direct (mitigation of residual pollution from point and diffuse sources) and indirect effects (improving biodiversity and other regulating or provisioning ecosystem services from rivers, stagnant waters and groundwater); operation and maintenance have to be secured; conflicting interests with land use (e. g. agriculture, urban development), navigation, hydropower, flood control); effects on water quality not always easily detectable	Cost effectiveness can be high; pricing of ecosystem services difficult and controversial; economic incentives and regulatory frameworks needed (e. g. implementation of IWRM), public awareness and participation necessary

Table 6-1 Selected mitigation options relevant for different sources of pollution (modified from UNEP 2016)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An output of the governance analysis would be an improved understanding of the most appropriate and effective governance approaches under different socio-economic circumstances that contribute to good water quality management. Another output would be descriptions of best governance practices worldwide.

7. Component 4: Analysis of governance approaches

7.1. Objectives

The first three components of the assessment provided indispensable but incomplete information to policymakers and stakeholders for coping with the global water quality challenge. Also critical is an understanding of the governance approaches (laws, regulations, enforcement institutions, and so on) that support the protection or restoration of water quality. As the *Snapshot* report concludes: "A key to managing water quality is good governance and effective institutions." Hence, the fourth component of the worldwide water quality assessment should have the following objectives:

- To identify and review various governance approaches – legal, economic, behavioural, technological, or cognitive – that are relevant to water quality management.
- Identify institutional barriers to water quality management and best practice examples of how to overcome these barriers on the national, regional or river basin level. For example, to include water pollution management as an element of "Integrated Water Resources Management (IWRM)" in a purposeful and targeted way (Borchardt et al. 2016).

An output of the analysis would be an improved understanding of the most appropriate and effective governance approaches under different socio-economic circumstances that contribute to good water quality management. Another output would be descriptions of best governance practices worldwide.

7.2. Approach

As opposed to the other components, it is not necessary to present the details of an approach to the governance analysis. Instead, it is recommended that the users of the analysis – policymakers and stakeholders – be involved in designing its details.

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Examples of how to organize this analysis can be taken from other assessments. For example, the Millennium Ecosystem Assessment developed a taxonomy of response strategies that can be useful in the worldwide water quality assessment (Table 8-1).

As in the other components of the assessment, two spatial scales would be analysed:

- On the *global scale*, governance approaches can be surveyed and best practices identified. The advantage of the global scale is the possibility of identifying "shining examples" of governance that can be adapted by other countries. The disadvantage is that results may be not be transferrable.
- On the *river basin scale*, the governance and institutional situation in several case studies can be investigated. The *Snapshot* report showed that a case study approach can provide useful governance-related information. Preliminary findings were that barriers to good governance of water quality included the fragmentation of authority in river basins, the lack of technical capacity, the lack of financial resources and a lack of public awareness (UNEP 2016). Furthermore it was found that these and other barriers could be overcome with action plans, collaborative authorities, and other instruments.

Taken together, the analyses of governance at the global and river basin scales can provide a crosscheck to each other and valuable complementary information.

LEGAL	Treaties
	International soft law
	International customary law
	International agreement; legislation outside environment sector
	Domestic environmental regulations
	Domestic administrative law
	Domestic constitutional law
	Domestic legislation outside the environmental sector
ECONOMIC	Command-and-control interventions
	Incentive-based
	Voluntarism-based
	Financial/monetary measures
	International trade policies
SOCIAL AND BEHAVIORAL	Population policies
	Public education and awareness
	Empowering youth
	Empowering communities
	Empowering women
	Civil society protest and disobedience
TECHNOLOGICAL	Incentives for innovation R&D
COGNITIVE	Legitimization of traditional knowledge
	Knowledge acquisition and acceptances

Table 7-1 An example of how to organize the analysis of options for governance. Taken from the "responses" typology of the Millennium Ecosystem Assessment (Chambers et al. 2005).

8. Organizing the assessment: maximizing success approaches

Assessments are complex activities with many potential pitfalls. But these pitfalls can be minimized and the chances of success increased by building on the experience of the several previous global environmental assessments. It is now generally accepted that the three trademarks of a "successful" global environmental assessment are high levels of *legitimacy* (acceptance by authorities), *saliency* (being widely known by authorities) and *credibility* (trusted knowledge being adopted as a basis for decisions). Experience from previous assessments suggest that *legitimacy* and *saliency* can be gained through the following:

- Having key policymaking and stakeholder institutions officially call the assessment into being and acting as visible sponsors of the assessment;
- Involving policymakers and stakeholders in the initial design of the assessment;
- Preparing a *theory of change* model before the assessment begins that describes how the assessment will have an impact on decision making. The model should include an explanation of how experts and stakeholders will interact during the assessment (e.g. during the scenario component), the potential users of interim and final results, how these results will be conveyed to users, and the type of outreach activities that would achieve the greatest added value for the assessment.
- Reviewing interim results with policymakers and stakeholders;
- Involving policymakers and stakeholders explicitly in the scenario building process (as explained in Section 6);
- Agreeing on a Policymakers Summary with policymakers and stakeholders;
- Engaging policymakers and stakeholders in conveying results of the assessment;
- Engaging policymakers and stakeholders in decisions about follow-up assessments or other follow-up activities.

Assessments are complex activities with many potential pitfalls, but these can be minimized and the chances of success increased by building on the experience of previous global environmental assessments.

The third criterion for success, *credibility*, is obviously linked to the level and kind of scientific engagement in the assessment. Credibility can be enhanced by:

- Engaging as many top scientists and other experts as practicable;
- Having adequate coverage of all pertinent scientific topics;
- Establishing a scientific review board to provide quality control of planning and execution of the scientific aspects of the assessment (criteria for documents to be reviewed, format of reporting, and so on);
- Conducting a rigorous peer-review process of assessment findings (this process could be designed by the scientific review board).

Unfortunately, there are trade-offs involved in achieving some of the actions above. For example, the number of stakeholders and scientists concerned with water quality issues is very large, but engaging them in large numbers (hundreds rather than dozens) may lead to skyrocketing costs and management difficulties for running the assessment. Therefore extra effort should be invested in the pre-assessment phase, to select a reasonably-sized yet representative group of partners and scientists to be active in the assessment. Of course, a much larger group can be engaged through a well-organized outreach and communications programme during and at the end of the assessment.

The selection of partners also has an important bearing on the success of the assessment. In addition to UN organizations, other potential partners could include the following entities with particular interest in water quality issues:

- Government organizations in North America, Europe and other OECD regions that could provide data and analyses of water quality from these regions (e.g. the European Environment Agency, the U.S. Environmental Protection Agency).
- Key universities and research institutions that can contribute to the analysis of the worldwide water quality situation
- NGOs concerned with protection of freshwater ecosystems
- Representatives from the private sector
- Trade organizations concerned with water quality issues
- Academic, governmental, or other institutions that can carry out river basin case studies.

9. Conclusions

As argued in this report, increasing pollution of freshwater systems, especially in Latin America, Africa, and Asia, are posing a risk to public health, food security and biodiversity. But developed regions are also facing continuing or increasing discharge of harmful chemicals, which threatens the quality of their surface and groundwater bodies. To meet this global water quality challenge, it is urgent to better understand the many dimensions of the world water quality situation, and for this a world water quality assessment is needed.

This report lays out a possible roadmap for such an assessment. It is argued that the Sustainable Development Goals (SDGs) will be a main driving force for environment and development over the coming two decades and therefore should provide the main context for this assessment. Therefore the assessment should give special attention to the water targets of the SDGs and the linkages between water quality and SDG goals and targets for public health, food security, biodiversity and other ecosystem services.

To provide the information and data needed to cope with the global water quality challenge, the assessment could be best divided into four components:

1. A **baseline assessment** of worldwide water quality, building on existing information and analyses, e.g. incorporating existing national/regional monitoring data; setting up freshwater monitoring groups; running new water quality surveys, some of which could involve citizen participation; and exploiting remote sensing data.
2. A **scenario analysis** that examines dynamic trends over the next decades in water quality and inland fisheries due to various socioeconomic driving forces.
3. An analysis of **mitigation options** that can protect or restore water quality, including technical options and management approaches.
4. An analysis of **governance approaches** for implementing mitigation options.

These activities require a partnership between scientists and other experts, policymakers and other stakeholders. Such a partnership will ensure the legitimacy and relevance of the assessment from the perspective of policymakers and other societal actors, and the credibility of the assessment from the viewpoint of the science community. Such a partnership will maximize the chances for a successful assessment and one that provides the knowledge needed to cope with the global water quality challenge.

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