Available online at www.sciencedirect.com
ScienceDirect
Aquatic Procedia 5 (2015) 104 – 110
Aquatic Procedia
www.elsevier.com/locate/procedia

World Water Week, 31 August to 5 September 2014, Stockholm, Sweden

Which water for which use? Exploring water quality instruments in the context of a changing climate

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Abstract

Extreme climatic events are resulting in more frequent, severe, and widespread drought and floods, leading to destabilization of ecosystems, and impacts on human livelihoods and supporting infrastructure. Such impacts also magnify the risk of contamination of both surface and ground water. Control of water quality requires law, policy, and regulatory instruments which are flexible, along with the capacity to enforce and implement them. This paper uses information from the "Compendium of Water Quality Regulatory Frameworks – Which Water for Which Use?" to explore how legal and regulatory frameworks are responding to water quality challenges in the context of a changing climate.

Peer-review under responsibility of Stockholm International Water Institute.

Keywords: water quality; legal instruments; guidelines and standards; climate change

1. Aim of the paper

Water quality is impacted by many factors including population growth, development, changes in land-use and hydrology, energy choices and climate variability and change. Extreme climatic events are causing droughts and floods to be more frequent, severe and widespread, resulting in destabilization of ecosystems, impacts on human livelihoods and supporting infrastructure. Flooding leads to contamination of water sources from wastewater and solid waste. Droughts can also affect water quality, because lower water flows reduce dilution of pollutants and increase contamination of remaining water sources (Wilk and Wittgren, 2009). Potentially, floods and droughts will also affect water volumes available for the energy sector, which increases the risk of contamination of both surface and ground water. For example, increases in energy demand are already having significant impacts on water quantity and quality, from oil and gas extraction – which requires large volumes of water – to other uses, such as cooling of thermal power plants.

Regulatory frameworks for the management of water quality – the system of rules defining legislation, implementing measures (regulations) and guidance documents (policies) – vary between and within countries, but also in degrees of efficiency. This paper explores how legal, policy and regulatory instruments and their implementation are responding to changing climate conditions and the consequent impacts on water quality. Few legal and regulatory texts directly consider the impacts of climate on water quality; however the right implementation approach can provide lessons on how to address these impacts and to ensure effectiveness of legal and regulatory instruments. Understanding how to manage water quality to ensure provision for a variety of uses (domestic,

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Peer-review under responsibility of Stockholm International Water Institute.
doi:10.1016/j.aqpro.2015.10.012

agriculture, industry, etc.) is important as available water resources become more dynamic in time and space due to climate shifts and changing behaviours.

The basis of the paper is the "Compendium of Water Quality Regulatory Frameworks – Which Water for Which Use?" a UN-Water initiative in collaboration with the International Water Association (IWA) and the United Nations Environment Programme (UNEP). The Compendium is a reference tool of the laws and policies regulating water quality for different uses at different geographical scales, which explores the gaps and weaknesses in their application.

Following an overview of the Compendium, the paper explores the policy relevance of examining water quality legal and regulatory frameworks in a climate-uncertain future. There is an analysis of the expected impacts of climate change on water quality, which is important to understand in order to develop the necessary response mechanisms to protect public health and the environment. This includes a more in-depth exploration of how climate will affect water quality and associated productivity in the energy sector. The paper then focuses on how climate change impacts on water quality create challenges for current legal and regulatory frameworks; followed by examples of implementation of regulatory instruments that provide some solutions to those challenges.

1.1. "Compendium of Water Quality Regulatory Frameworks – Which Water for Which Use?"

The Compendium aims to fulfil the objectives of UN-Water's Thematic Priority Area on Water Quality, while also complying with targets defined through successive World Water Forums and several of the key objectives highlighted in the Rio+20 Communiqué. The Compendium provides a foundation for governments and other stakeholders to prepare frameworks that guide the use of water quality which is fit for purpose. This includes exploring the challenges and opportunities regarding their implementation such as climate variability and change, which impacts the availability of water resources.

The main objectives of the Compendium are to:

- provide a state-of-the-art overview of water quality guidelines and standards currently available worldwide, with input from all relevant stakeholders,
- provide a reference to guide decision-makers in determining which water quality is suitable for which use in order to promote efficient use of water resources,
- promote wise use of water resources.

The Compendium is an evolving tool consisting of a narrative analysis report of selected law and policy instruments regulating water quality; case studies highlighting best practices and methodological approaches adopted; and a database of the collected instruments. The intention is for the Compendium to continue to be populated with new information through an online database where information on instruments regulating water quality can be submitted, reviewed and shared.

2. Policy relevance

2.1. Water quality legal and regulatory frameworks – challenges in a climate-uncertain future

"Water quality has so far been a neglected topic in global debates" (UN-Water, 2014a, p.12), but the growing evidence of the effects of increasing population and water demand across sectors, coupled with climate variability and change, on water supply is raising attention in the global post-2015 development agenda (United Nations, 2012). The importance of highlighting water quality is expressly addressed in the proposal of the UN General Assembly's Open Working Group for the Sustainable Development Goals through target 6.3. This target reads, "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 increasing recycling and safe reuse by x% globally" in order to achieve the goal for ensuring availability and sustainable management of water and sanitation for all (United Nations, 2014).

In the past 15 years, several substantial reforms to water governance systems have been developed to address growing pressures including environmental degradation, growing human water demands and global climate change. South Africa, Australia, the European Union and Russia have all established innovative reforms to redesign their approaches to water management which recognize the problem of declining ecosystems and water quality. There has also been a recognition and integration of innovative approaches to address water quality regulation including decentralized water decision-making and increased stakeholder participation (Palaniappan et al., 2010).

Regulatory frameworks need to align with global goals and targets enabling more efficient water management. This requires analysis of the water cycle including changing pressures due to climate change and increasing resource demands from other sectors, such as energy and food (OECD, 2014). To better understand what frameworks could effectively manage water quality, a wide range of law, policy and regulatory instruments for water quality management for different uses were analyzed as part of developing the Compendium. A selection of the compiled instruments were analyzed in more depth including scope, management frameworks for application, parameters and indicators for monitoring, and challenges and opportunities around implementation.

The instruments analyzed not only covered a wide variety of water uses, but also were selected to provide examples from different landscapes and geographic regions; all of which are increasingly under pressure from a growing population and consequential competition for water resources due to the effects of climate change and climate variability (WWAP, 2012).

The in-depth analysis and review of legal, policy and regulatory instruments found that a key challenge was their lack of flexibility or adaptability when regulating water quality. This can reduce their effectiveness as conditions change including climate, land-use and increasing population densities. In the case of climate change, provisions to prevent or mitigate its effects on water quality are rarely incorporated. This is because many existing laws that intend to protect health and natural resources and promote conservation were drafted under significantly different conditions, so the current challenges can result in making them less effective (Hansen and Pyke, 2007). In order to achieve their original goals, the laws, policies and regulations require careful assessment of long-standing assumptions, as well as decisive action to change regulatory practices in ways that accommodate, offset and mitigate climate change (Hansen and Pyke, 2007).

According to Hansen and Pyke (2007), to be able to understand the factors affecting water quality will require monitoring systems that can separate climatic and non-climatic factors. For example, the US EPA as well as the EU Water Framework Directive uses a system of bioindicators such as fish, aquatic insects and other organisms that have well-known responses to changes in water quality. However, these bioindicators will also respond to changes in both climate and water quality; for example elevated temperature and altered water chemistry can exacerbate the toxicity of pollutants. So there needs to be careful assessment whether toxicity of a pollutant was of a certain level at source or whether it has become more toxic because of temperature or changing water levels. Consequently, there needs to be a clear understanding of the response of specific bioindicators to changing conditions and specific selection of indicators with methods that allow for partitioning between climatic and non-climatic impacts (Hansen and Pyke, 2007).

Parameters and indicators provided by a particular water quality instrument are based on scientific evidence but determined by policy decisions that respond to the need of a particular activity and (ideally) to the status of the resource at a given scale. Effective regulation of water quality is an exercise in achieving sustainable development that synthesizes the balance between considerations of human and environment health with economic affordability and social acceptance. Therefore, determination of adequate standards will necessarily differ between geographies but also between developed and developing economies. Given that the local effects of climate change on water resources and their social, economic and even political consequences are still uncertain, it is hard to define water quality standards that take these effects into account. Even in countries with comprehensive policies and regulations, water quality is not protected unless the regulations are effectively implemented. This is a major challenge as there is often a lack of institutional capacity necessary to establish, monitor and enforce water quality policies (Palaniappan et al., 2010).

The solution is not necessarily redrafting laws, but rather ensuring there are instruments and tools which allow achievement of the original water quality goals. "Long-term commitment to new learning and new philosophy is required of any management that seeks transformation. The timid and the fainthearted, and the people that expect quick results, are doomed to disappointment" (Deming, 1986). Despite the challenges, traditional approaches to manage water quality can be tailored to cope with eventual effects of climate change, adding risk-based approaches such as water safety planning[1]. Lessons learned can be found in current water quality laws and policies that either directly incorporate mentions to climate change or have developed complementary tools and innovative implementation approaches to address impacts including the risk of climate variability on water quality.

3. Analysis: understanding and responding to the impacts of climate change on water quality

3.1. Overview of expected impacts of climate on water quality

Understanding how climate variability and change will affect water resources, especially water quality for different uses, is important to be able to develop the necessary response mechanisms to protect public health and the environment. Changes in patterns, intensity and duration of precipitation will affect water quality; for example, intense rainfall over short periods increases the amount of sediment, nutrients and other toxins in water bodies due to heavy runoff (UNFCCC, 2011; WEPA, 2014). Measuring changes in water quality as result of climate variability and change is difficult due to the inherent complexity and interlinks between the nature and magnitude of the use of fresh water resources by a range of sectors (UNFCCC, 2011). Furthermore, climate impacts on water quality will affect productivity of all sectors, and without more efficient, innovative and wiser policies and regulations, it is expected that the relative importance of water uses will shift by 2050, increasing competition between uses (OECD, 2012a).

The agricultural sector is expected to suffer the impacts of variable stream flow in areas where climate change impacts mean increased uncertainty of rainfall patterns (UNFCCC, 2011). Such impacts may encourage reallocation of land for crops and cattle, and implementation of more profitable – but not necessarily more sustainable – technologies and practices. Assuming no policy or economic response, the impact of climate and the consequent shifts in land-use could result in changing pollutant runoff and leaching and erosion rates, which could increase the level of water quality pollution from non-point sources such as agriculture (OECD, 2012b).

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[1]A water safety plan is a plan to ensure the safety of drinking water through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer.

Climate change is also expected to have a range of adverse effects on populations where the water and sanitation infrastructure is inadequate to meet local needs (UNFCCC, 2011). Within distribution and storage infrastructure, increased temperatures combined with reduced flows due to restriction on water use or water scarcity, provide more favourable conditions for some mesophilic opportunistic pathogens (e.g. *Naegleria fowleri*). Increased temperatures reduce the stability of chlorine residuals in the distribution and storage network, further exacerbating problems in controlling opportunistic pathogens (WHO, 2014a). In such cases, management frameworks such as water safety plans are invaluable to ensure adequate data on water quality is being collected, and that control measures are in place to deal with water quality fluctuations. Such control measures include changing concentrations of chemical treatment, enhanced monitoring of inflows and outflows, and protection of water sources.

The energy sector will be impacted by a number of climate effects. For example, storage capacity and consequently hydropower generation and downstream flow management may be affected in regions where upstream flow is impacted (e.g. the timing of snow melt changes). Floods may affect energy infrastructure, while lower flows in vulnerable regions could also threaten thermal plants that require water for cooling (UNDP, 2006; UNFCCC, 2011).

3.1.1. Impacts of climate on water quality for energy production

Some of the expected effects of climate change and variability on water quality are similar to some of the impacts of increased water demand and use from the energy sector. Impacts of climate change include higher water temperatures, which reduce the amount of dissolved oxygen in the waters and consequently the potential to self-purify. Similarly, in the case of energy production, an increase of water use for cooling by thermal power plants will cause higher water temperatures through discharges, threatening the viability of aquatic ecosystems (UN-Water, 2014b; UNFCCC, 2011). Thermal-electric power plants in the US withdraw 40 per cent and consume 4 per cent of the country's fresh water resources; 90 per cent of their total water demand is for cooling systems (Chu, 2014). In the case of nuclear power plants, the highest volume consumed corresponds to cooling needs. Negative impacts on water quality from thermal loads can include overgrowth of blue-green algae, "changes in the composition of plankton and dynamics of its numbers, disruptions of the structure of fish communities, and microclimatic changes" (Hess, 2014).

Water temperature and availability is a decisive factor for power generation. In France, power generation may be limited in very hot summers. In the USA, plants that use water for cooling directly from rivers need to reduce output generation when temperatures are too high. For example, the Tennessee Valley Authority's Browns Ferry nuclear power plant must operate at half its capacity when river temperature is over 32 degrees Celsius (Hess, 2014). Furthermore, the location of the plants responds to low temperature advantages. In the UK, nuclear power plants use direct cooling and are located in coastal areas. In Turkey, the output generation of plants located on the Black Sea coast would be 1 per cent higher than those that were located in the Mediterranean, where average temperatures are 5 degrees Celsius higher (Hess, 2014).

Alternative water sources for power generation can provide a solution for climate variability and avoidance of negative impacts on water quality (Argonne National Laboratory, 2007). These could include municipal treated wastewater effluents, mine water from oil and gas activities, agricultural drainage, saline ground water and storm water. For example, the Palo Verde nuclear power plant in the USA uses 98 million m^3 of treated municipal wastewater a year (Hess, 2014; State of Arizona, n.d.). However, these practices need to consider the impact not only on water quality for operations, but also on public and ecosystem health (Chu, 2014).

Another issue to consider is how the recent volatility in energy prices has impacted the exploitation methods for gas and oil reserves in terms of water use and consequences for water quality. As oil prices increase, it becomes more economically feasible to extract through processes such as hydraulic fracking or from tar sands. These approaches require large quantities of water which becomes polluted.

3.2. Responsiveness of current regulatory instruments to water quality from a changing climate

Emerging challenges such as those described above can be overcome with rapidly evolving technology solutions and adaptive infrastructure. However, accessing and implementing such solutions needs regulators that are prepared to respond in a timely manner. Capacity building and financial resources are often the limiting factor resulting in gaps between places with similar activities, technologies and regulations to deal with water quality.

Consideration of different water qualities for different uses when regulating water quality may increase efficiency in areas with water scarcity. Water reuse and water recycling regulations and policies can address these needs but more attention is needed to ensure the right approach. Strict regulation can hinder reuse projects, but flexible regulation may also have drawbacks. In France, a prescriptive approach of legal instruments was undertaken to regulate water reuse. Standards based on tolerable risks to human health were established for using reused water for irrigation; however, the high costs of ensuring compliance resulted in low rates of application.

The Australian Guidelines for Water Recycling (AGWR 2006) promote a risk management framework based on the Australian Drinking Water Guidelines (ADWG 2004) and the 2011 WHO Guidelines for Drinking Water Quality. Their implementation requires that water treatment technologies are validated before a particular recycling scheme is made operational. Although the guidelines describe the concept, they do not establish a consistent approach for validation of treatment technologies across the country. As a result, stakeholders describe the current scheme as complex, slow and costly, hindering innovative development

(Aither, 2012; Muston and Halliwell, 2011). Despite the higher degree of acceptance compared with France, there was still a high cost for risk management in the case of small-scale users, which may hinder innovation (David and Hercule-Bobroff, 2014).

These examples are not about inadequate regulatory provisions or policies but about the need to adopt overarching and coherent approaches for their implementation. Lack of provisions directly addressing the effects of climate change can be mitigated by complementary instruments that assist an adaptive and flexible approach to manage water quality. There needs to be clear guidance from regulators to reduce the impacts of climate change (such as floods and droughts) that result in interrupted supply and compromised water quality, in turn affecting human and environmental health as well as economic production. Below are three examples of agreements which incorporate approaches that can take into account the impact of climate on water quality. This is followed by an example of a management framework, Water Safety Planning, which can be a mechanism to reach drinking water quality standards and ensure risks from climate change (and other factors) are mitigated.

3.2.1. The 2005 Colorado River Interim Guidelines

The Colorado River is a good example of incorporating new knowledge and lessons learned to manage the known effects of climate variability while addressing water quality, without drafting new laws. After a multi-year drought compounded with increasing water demands, the USA Treaty Section decided in 2005 to establish the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead (USBR, 2007). The history of this regulatory framework has evolved through implementation and practice from an absolute disregard of water quality aspects towards an innovative model of water management.

The 1944 Treaty (and subsequent minutes of the International Boundary and Water Commission) provides the basis for water allocation between the US (upstream) and Mexico (downstream) in the Colorado River basin (US Government, 1944). Naturally, its original text did not contain direct reference to the quality of the water to be delivered (Cooley and Gleick, 2011). However, from a Mexican perspective the Treaty expressly acknowledged different water uses; meaning that, if the water delivered was unfit for the purposes recognized in the text, the USA would be acting in a manner that was inconsistent with the Treaty (Umoff, 2008). Such obligations were consistently controverted by the USA, causing diplomatic and political tensions between the parties. In order to solve the rapid escalation of the conflict that occurred after a salinity crisis in the 1960s, agreements were signed in 1965 and 1972 to solve the argument but without declaring if there had been any violation of the Treaty. Solutions included establishing a compensation scheme and protecting the areas affected by the excess of salinity.

The 2005 Colorado River Interim Guidelines use modelling to determine potential effects on water quality associated with each alternative action (use) and its results. The guideline addresses the varied and unpredictable impacts of climate change, which in turn facilitates the use of alternative water sources, as in the case of recycled water for power plant cooling.

3.2.2. The Great Lakes Water Quality Protocol of 2012

The Great Lakes Water Quality Protocol of 2012 to The Great Lakes Water Quality Agreement between Canada and USA is one of the only instruments to clearly address the impacts of climate change on water quality (annex 9 of the protocol). This instrument establishes an obligation to coordinate efforts between the parties in order to identify, quantify, understand and predict these impacts; the protocol also binds the Parties to share such information in a timely and comprehensive manner. The system established in the protocol also requires the Parties to identify and provide assistance to coastal communities to understand the impacts of climate change on water quality. Such efforts must be transposed into regional-scale models linked to each chemical, physical and biological aspect of the Great Lakes Basin ecosystem (US EPA, 2012).

The protocol is implemented and enforced by an International Joint Commission (IJC) – established by the same Treaty. The IJC acts in cooperation and consultation with local authorities and the public, via recommendations to: assist in the implementation of the treaty; collect and analyse data and information; and assist in the coordination of joint activities. The conflict resolution system of the treaty, however, does not provide the Commission with powers to act and solve independently, and impose decisions over the Parties. This could eventually limit the effective implementation of this instrument and the protocols.

3.2.3. Agreement on Water Quality Protection of Transboundary Waters between Kazakhstan and China

Another case of a policy or legal instrument integrating and addressing the impacts on water quality from climate change is the Agreement between Kazakhstan and China on Water Quality Protection of Transboundary Waters (Beijing, 22 February 2011; FAO, 2011). The agreement creates a joint commission for its implementation and enforcement that is divided into two working groups: one in charge of analysis, monitoring and evaluation of the waters; and the other in charge of emergency response and prevention (such as those caused by the impacts of climate change). There is limited available information on the implementation process, but the case is a good starting point and example for how the impacts of climatic change such as floods and droughts can be incorporated into transboundary treaties.

3.2.4. Water safety planning

Management frameworks such as water safety plans (WSPs) provide a clear preventative and flexible approach for evaluating the risks to individual water supplies from climate change (WHO, 2014a). The approach incorporates proactive risk management along the entire supply chain from catchment to the point of use and includes defining hazards, assessing risks, and identifying and validating control measures to ensure safe drinking water to consumers (WHO, 2009). Consequently, the water safety planning management cycle can absorb the acute impacts of hazards such as floods and droughts due to climate variability and change. The management framework of WSPs can be modified to adapt to long-term climate change by identifying appropriate control measures which respond to how the water supply system may be affected by specific climate change effects (6th World Water Forum, 2012). The World Health Organization (WHO) has been developing guidance to build resilience into water safety planning which highlights where opportunities lie to enhance the WSP by considering both the planning for safe water provision under changed future conditions and the management of extreme weather-related conditions that may become more frequent as the climate changes (WHO, 2014a).

Table 1 shows an example from Nepal of how the WSP process supports climate change impact identification and contingency planning (WHO, 2014b).

Table 1. WSP adaptation to climate change. Source: WHO (2014b)

WSP step	Adaptation to account for climate change
Identify and review hazards and hazardous events	Simply identify any new hazards or hazardous events, or those anticipated in future, due to climate change as part of routine WSP review and monitoring
Assess and regularly reassess risks from hazards	Assess whether risks from existing hazards have increased, or may be expected to increase in future, as a result of climate change-influenced hazardous events
Identify and implement control measures	Identify what measures may need to be taken to address new hazards/hazardous events or increased risks of existing hazards or those that can be anticipated due to climate change
Monitor	Continue to monitor for climate change impacts

4. Conclusions and recommendations

Water quality will continue to be significantly affected by unavoidable climate change. In order to reduce impacts on public health, environment and economic productivity, there needs to be not only improved data collection, health and environmental studies, but also incorporation of climate understanding into management and regulation.

The examples summarized in this paper illustrate how the right approach in implementation can help to address the effects of climate change on water quality and to ensure effectiveness of legal and regulatory instruments. Lack of direct provisions can be mitigated by complementary instruments that assist an adaptive and flexible approach to managing water quality.

The development of the Compendium provides an opportunity to establish a dialogue between stakeholders, from regulatory authorities to water consumers. It is also a space to consider how policy and legal instruments are addressing climate and energy pressures and what approaches are available to control water quality, while considering the increasing demands on water resources. From the analysis of the Compendium, used to develop this paper, several provisions have been identified to develop or update water quality regulations to address the impacts of climate change:

- Assessing the what, how and when of climate change impacts on water quality.
- More efficient water management requires better understanding of the water cycle and the changing pressures due to climate change and increasing resource demands across sectors.
- Explicit provisions to prevent or mitigate climate change effects on water quality are rarely in place; regulatory frameworks were drafted under different conditions so current challenges lessen their effectiveness. The solution is not necessarily redrafting laws, but rather ensuring there are instruments and tools which allow achievement of the original water quality goals.
- Effective instruments create the right balance for sustainable development by considering human and environment health on one side with economic affordability and social acceptance on the other. Consideration of different water qualities for different uses when regulating water quality can be an opportunity to adapt availability for a more efficient use of water resources.
- Legislation offers limited flexibility to cope with the challenges imposed by climate change in water quality. However, examples like the agreements between Canada and United States and China and Kazakhstan are evidence that regulatory frameworks are moving towards increasing cooperation and coordination between stakeholders.
- Coherence and coordination that enables innovative management approaches are as important as good standards. Adequate instruments need to be implemented efficiently by informed regulators. Capacity building and financial resources are needed for better technologies and infrastructure that guarantee good water quality.
- A clear preventative and flexible management framework can evaluate and address changing risks. Approaches such as WSP incorporate proactive risk management along the entire supply chain absorbing the acute impacts of hazards due to climate variability and change.

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