Issues of drinking water quality of small scale water services towards climate change
I. Delpla, E. Baures, A. V. Jung, M. Clement and O. Thomas

ABSTRACT

As climate change could impact water quantity and quality, important concerns are related to water quality degradation in small scale water services (SSWS). SSWS using surface waters resources (rivers and lakes) for drinking water production are particularly vulnerable to short term transient events due to their low adaptation capacity and their lack of support and technical knowledge compared to major centralized systems. Based on weather and water quality databases, a case study was conducted on a SSWS in Brittany (France) pumping from surface water. Results show an important vulnerability in treatment efficiency related to the lowest and highest river flows and provide first assumptions about the impacts of an increase in extreme weather events with climate change on drinking water quality.

Key words | climate change, drinking water, small scale water services, water quality, water treatment

INTRODUCTION

Global change affects water quality through several factors. The most evident is climate change with namely global warming increasing the number of extreme meteorological events (heavy rain falls, floods or droughts). A recent review (Delpla et al. 2009) underlines that the main consequences on water quality is an increase of total and dissolved organic carbon (TOC and DOC), nutrients (nitrate namely) and possibly total suspended solids (TSS) and pathogens (Hunter 2003; Zwolsman & van Bokhoven 2007; Van Vliet & Zwolsman 2008). Heatwaves also promotes harmful cyanobacteria blooms (Jöhnk et al. 2008). A second factor is the evolution of land use with for example intensive agricultural practices and soil waterproofing in urban area, increasing TSS, nutrients and micropollutants concentration with run off. The third factor is a consequence of industrial efforts by reducing water and air discharges with for example acid rain decrease also leading to DOC increase in lake water in glaciated landscapes (Monteith et al. 2007).

The main consequence of water quality degradation under global changes concerns small scale water services (SSWS) pumping in lakes, at streams surface or after bank filtration, the larger waterworks being designed to adapt the treatment with the quality variation of the resource. Among water quality degradation factors, chemical and physical (increase of concentrations of chemicals and suspended solids) and biological ones (pathogens occurrence) are often correlated with extreme meteorological events like heavy rainstorms or droughts. Moreover, as SSWS are dispersed in rural area, the impact of chemical risk associated with some micropollutants or emerging substances (namely pesticides and pharmaceuticals) is potentially present. Starting from the French water quality database for SSWS, the chemical evolution of water quality with extreme meteorological events (from lowest flows and droughts to highest flows and floods) is studied for one SSWS on a period of near 20 years. The evolution of water quality is examined from samples taken both from the resource (river water) and the distribution network.

MATERIAL AND METHODS

In Brittany, 80% of drinking waters are supplied from surface waters. Moreover, surface water quality is affected by strong
agricultural pressures (organic matter production: 4.7 billions of tons/year) and, topographic and geologic conditions also favour the leaching of pollutants from agricultural area to rivers (low slopes and impervious soils).

For this work, one SSWS was selected by taking into consideration the amount of people supplied, the water treatment plant capacity and the origin of water (surface water). This SSWS is located in Brittany in a little river basin of 468 km² under strong agricultural and related industrial pressures. Relevant information about the studied water supply service and its resource is presented in Table 1.

The presence of a small dam allows drinking water treatment and distribution for the whole population even in droughts period with river flow less than 50 L/s.

Data are provided from the database SISE-EAUX (Agence Régionale de Santé Bretagne) for water quality (resource and drinking water network) and from the database HYDRO (Ministère de l’Ecologie et du Développement Durable) for the river flows measure at a limnometric station in front of the treatment plant. The data acquisition covers the period 1993–2009. Air temperature is provided by the weather station of Rennes Saint Jacques, located at 18 km from the site.

The choice of water quality parameters to be included was carried out with regard to the aim of this study. Parameters relevant with regard to drinking water quality evaluation (TOC, nitrates, turbidity) are considered in the data analysis. Micropolutants (namely pesticides) were not included due to their scarce determination at the beginning of the studied period. Concerning the choice of environmental parameters external to water quality, river flow was only considered, taking into account the lack of historical meteorological data like rain volume or intensity, only known from the weather station of Rennes Saint Jacques (see above).

Before examining the main outcomes of this work, it has to be underlined that using water quality database provided by the sanitary monitoring program may lead to heterogeneous series because sampling frequency is variable from year to year and may be low for some. Moreover, sampling frequency varied also between resource and treated waters, from 4/year to 12/year respectively. On the other hand, changes in parameters determination also occurred in this period. Thus, in order to extend the dataset for TOC results, which was less frequently measured in the resource than permanganate oxydability (OxA), a statistical relationship between these parameters was used (TOC = 1.045*OxA + 0.34, R² = 0.83, n = 59), to include estimated TOC data from OxA. Finally the use of TOC instead of DOC is of less importance, with very low suspended solids concentration in the great majority of samples.

RESULTS

Starting from raw data (resource quality and drinking water network, respectively referenced as RES and SSWS), the evolution of some main parameters is firstly studied both for droughts or low water levels and floods or high water level periods. In a second time, the frequency of water quality limits exceedances is given for these events, namely for TOC.

Before studying the evolution of parameters during droughts and floods let’s show their yearly evolution (Figure 1).

By comparing TOC concentration and flow rate evolution during the period 1993–2009, it could be noticed that highest TOC values are observed during wet periods (1993–1995 and 1998–2001). Air temperature didn’t show significant evolution during the period considered, even if an increase in warm days and mean temperature have been observed in Brittany during the last sixty years (Tréguer et al. 2009).

The first step of our study deals with the examination of the impact of extreme meteorological events (from droughts to floods) on water quality of the resource (RES) and drinking water network (SSWS). Figure 2 presents the relation

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Catchment area</th>
<th>River Q (mean)</th>
<th>River Q (mean dry period)</th>
<th>River Q (mean wet period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 m</td>
<td>468 km²</td>
<td>3.1 m³/s</td>
<td>1.9 m³/s</td>
<td>4.3 m³/s</td>
</tr>
<tr>
<td>Treatment process</td>
<td>Mean daily volume</td>
<td>Annual Volume</td>
<td>Inhabitants supplied</td>
<td></td>
</tr>
<tr>
<td>Advanced treatment (Activated Carbon) + Bleach/Ozone</td>
<td>1243</td>
<td>640000</td>
<td>5600</td>
<td></td>
</tr>
</tbody>
</table>

²For 43 years.
³Calculated for five-year dry and wet period values for the river studied.
between river flows and parameters values during droughts or severe low water levels.

The main outcomes are first a slight concentration phenomenon for the TOC both in resource and drinking waters (TOC values decreasing with flow). On the contrary, the evolution of nitrates concentration showed a very different trend with the lowest values for the lowest flows. This typical evolution can be explained by the high mobility of this substance and consequently the reduced supply from soil leaching under low hydrological conditions (Van Vliet & Zwolsman 2008), but also by biomass nitrates consumption favoured by very low water speed. No clear trend could be noticed for turbidity. Finally, no relation between air or water temperature and flows can be drawn.

For high water level or floods, the relations between river flow and parameters values are displayed on Figure 3. Despite the number of data less numerous than for low water levels, the main outcomes are a slight dilution phenomenon for nitrates, and an increase in concentrations for TOC and turbidity. TOC and turbidity show a distinct evolution during high flow levels, probably related to an increase in run off and consequently in transport of organic matter and particles from land to the resource. As for low water levels, no relation between air or water temperature and flows can be drawn.

In order to clarify the nitrates evolution during dry and wet period and extreme events (droughts and floods), a relation with TOC is shown on Figure 4.

The decrease in nitrates concentration for the dry period could be explained by the biomass consumption at low water velocity (high residential time), explaining the increase of TOC. The decrease in nitrates concentration is also observed for high water levels (Q > 4.3 m³/s) with a lower slope and can be explained as discussed above by TOC and nitrates behavior with higher flows.

After the examination of the impact of climate change on drinking water quality (SSWS) and resource (RES), the second step of this study consists in a comparison of parameters data with quality limits or references of quality. These two thresholds give useful information with respect to regulation compliance and health risk assessment. Table 2 presents the percentage of samples with higher TOC concentration than the French limit of quality (QL) for catchment (10 mg/L) and the reference of quality (QR) for the drinking water.
network (2 mg/L) set by the “arrêté du 11 janvier 2007”. It should be noticed that only the quality limit is imperative in France.

The main conclusions drawn from Table 2 are:

- for low water levels or droughts period, an exceedance of 5% and 35% respectively for resource and drinking water;
- for high water levels or floods period, an exceedance of 33% and 60% respectively for resource and drinking water.
- In between, an exceedance of 61% only for drinking water (with less data and values close to 2 mg/L).

Among the exceedances values in all classes for drinking water around 50% of the exceeding values are lower than 2.5 mg/L and the more recent samples (since 2005) shows less excess than before. However efforts have to be made for regulation compliance. However, the worst scenario is obviously for high water levels and floods with about a third of samples exceed the limit of 10 mg/L for the TOC, needing a strong adaptation capacity of the treatment plant.

**DISCUSSION**

For SSWS, an international mobilisation is carried out in the frame of the implementation of WHO water and Health Protocol, including water supply during extreme weather events. Even if experience sharing on good practices in the safe operation of water supply in rural areas subject to the impact of short-term critical situations is planned (UNECE/WHO 2009), the regulatory trends is to simplify the sanitary control by introducing a risk assessment/risk management approach, as in Europe with the future revision of the drinking water directive.

Therefore, the requirement for operational monitoring should be simplified (reduced) if there is evidence that a substance is not present or not used in the catchment. Unfortunately, emerging substances like pharmaceuticals are not yet monitored in drinking water but can however be present (Mompelat et al. 2009). In this case, new monitoring tools and procedures for on site use and more appropriate laboratory monitoring methods must be proposed. New sampling
strategies must also be designed to cover the water quality variability around extreme weather events.

Besides water quality monitoring, decision support system should also be proposed for safe water supply management and risk prevention. For example, water treatment must be adapted to face with transient degradation of raw resource in order not only to ensure safe water to end users but also to reduce trihalomethanes (THMs) precursors (Teksoy et al. 2008). Finally, as recommended by the report on the workshop on safety of SSWS in the European region (UNECE/WHO 2009), laboratories that specialize in emerging health risks, including cyanobacterial blooms, should be encouraged to work with small-scale water suppliers to assist and strengthen current health risk assessment.

![Figure 3](https://iwaponline.com/wst/article-pdf/63/2/227/445165/227.pdf)

Figure 3 | Relation between river flow and parameters values during floods or high water levels (resource-RES and network-SSWS).

![Figure 4](https://iwaponline.com/wst/article-pdf/63/2/227/445165/227.pdf)

Figure 4 | Relation between nitrates and TOC in the resource for dry (*) and wet (+) periods.

<table>
<thead>
<tr>
<th>TOC max value (mg/L)</th>
<th>&gt; 10 (QL)</th>
<th>&gt; 2 (QR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow condition (m³/s)</td>
<td>RES (%)</td>
<td>SSWS (%)</td>
</tr>
<tr>
<td>Droughts &amp; low water levels</td>
<td>Q &lt; 1.9</td>
<td>4.8 (n = 84)</td>
</tr>
<tr>
<td>Median water levels</td>
<td>1.9 ≤ Q &lt; 4.3</td>
<td>0 (n = 26)</td>
</tr>
<tr>
<td>High water levels &amp; floods</td>
<td>Q ≥ 4.3</td>
<td>33.3 (n = 33)</td>
</tr>
</tbody>
</table>

Table 2 | Frequency of quality standards exceedances for extreme conditions of river flow (from droughts to floods) (n – number of samples of the class)

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2Average value on 43 years.
CONCLUSION

The findings of the present study highlights expected results for the variation of the water quality of the resource:

- for droughts periods, a decrease in nitrates concentration,
- for floods, an increase of TOC concentration and a decrease of nitrates levels.

For the quality of drinking water of the studied SWSS, the worst situation is related to high water levels and floods with a rather high frequency of TOC quality reference exceedances. These first conclusions are of great importance considering the possible increase in frequency and intensity of droughts and floods in the future with climate change. Another parameter such as DOC is essential considering its impact on quality of treated waters and has to be studied, especially in SSWS. Further studies will also include other water quality parameters like pesticides and other sites.

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