Impact of anthropogenic salinity on the aquatic biocenosis of the River Moselle

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Summary of a study performed by the LIEBE Laboratory (Paul Verlaine-Metz University, CNRS UMR 7146) at the request of the CIPMS.

Salinity is defined by the total quantity of dissolved minerals in water. Increasing salinity is observed along the River Moselle due both to the contribution of anthropogenic inputs of chlorides (or other ions / salts) and to natural salinization. At the request of the International Commission for the Protection of the Mosel and Saar (CIPMS), a literature review has been carried out to synthesize the available knowledge about the impact of chloride on the physiology of organisms and on aquatic biota.

THE SALINITY OF THE RIVER MOSELLE

The natural salinity of the River Moselle is related to a specific geological context: a tributary like the River Seille brings naturally highly mineralized water to the Moselle. But today much of the total salinity of the Moselle is of anthropogenic origin. On the upstream part of the river, the confluence with the River Meurthe marks a longitudinal break in the mineralization of water (Figure 1).

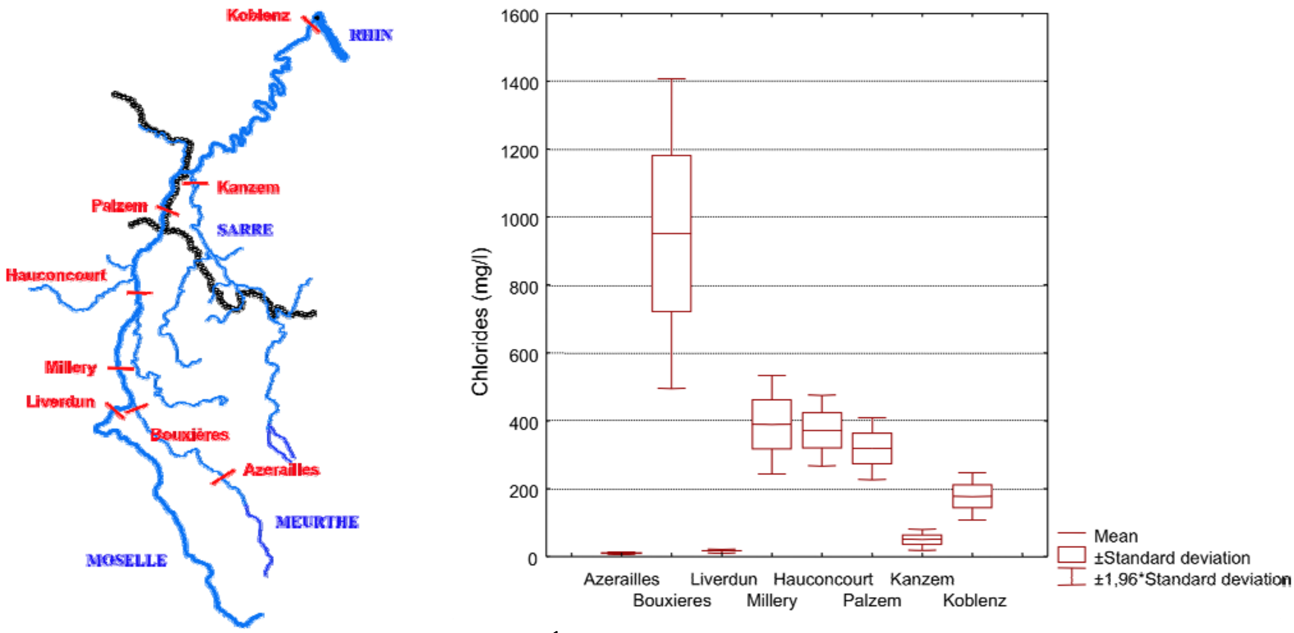

Figure 1 : Concentrations of chlorides (mg.l^{-1}) measured monthly in 2008 at two stations on the Meurthe (Azerailles, Bouxières), five stations on the Moselle (Hauconcourt, Liverdun, Millery, Palzem, Koblenz) and one station on the Saar (Kanzem). The confidence interval of the maximum and minimum values shown is 95%.

In its downstream part, the River Meurthe is the outflow of saline discharges (especially calcium chloride, $CaCl_2$) from the Lorraine plants related to soda production. The conductivity of the River Moselle increases from 383 µS/cm (17.2 mg/l of chlorides) to 1578 µS/cm (389.3 mg/l of chlorides) after the confluence with the Meurthe (3230 µS/cm and 951.8 mg/l of chlorides). The total salinity is four times higher and the chlorid concentrations are 22 times higher than upstream of the confluence.
Further along the Moselle, the waters from the Lorraine iron basin add significant amounts of sulphates (119.4 mg/l at Palzem versus 77.3 mg/l at Hauconcourt - monthly averages of 2008). The salinity of the Saar, primarily from sulfates, is relatively lower than that of the Moselle. Total salinity is lower at Koblenz due to dilution effects, although the monthly average concentration of chlorides is at least 177 mg/l in 2008 and that of sulphates is 82 mg/l. An important consequence is that the overall increase in salinity is not solely due to chlorides even though, together with calcium and bicarbonate ions, they make a large contribution to total water salinity.

The temporal analysis of the decade 1998-2008 shows that inter-annual variations are more marked at the German stations than at the French ones. As regards inter-annual variations, the lowest average salinities were observed in 2000 and 2001 while the highest were measured in 2004, 2005 and 2006. These variations more or less closely follow the hydrology, with dry years that generate on average more saline waters, and years with higher flows that lead to lower salt concentrations.

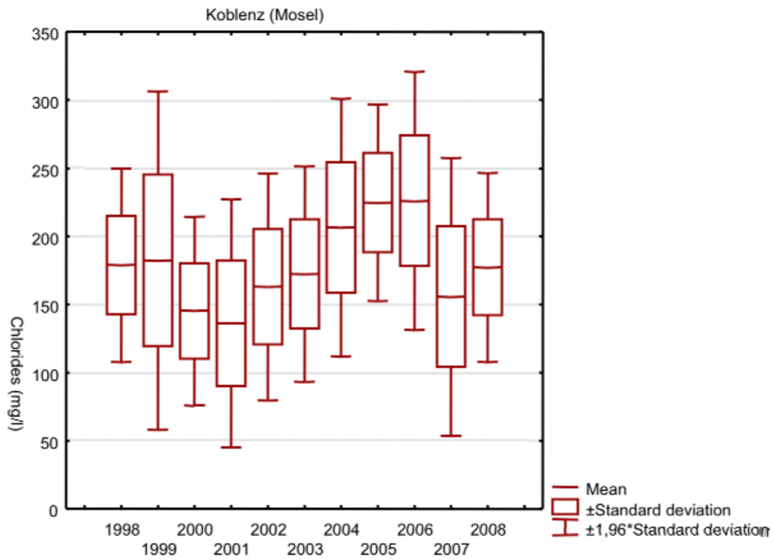

Figure 2 : Annual changes in chloride concentrations (mg.l^{-1}) measured monthly between 1998 and 2008 on the River Moselle at Koblenz. The confidence interval for the maximum and minimum is 95%.

Impacts on organisms and biocenosis

The thresholds at which biological communities are significantly affected by salinity are relatively low, between 1 and 2 g/l according to the different authors. Above 3 g/l, the consequences of increasing salinity significantly affect invertebrates, algae or macrophytes. The River Moselle between Millerey and Palzem has a total salinity of about 1 g/l whereas the downstream part of the Meurthe reaches 2.2 g/l. An increase in salt concentrations usually causes a rapid reduction in the number of species and individuals. Even though the limit of 1 g/l is often cited, we must bear in mind that our available knowledge come from studies on the downstream sections of rivers, where salt intake is generally high and has been in place for a long time.

The sensitivity of different biological groups to salinity varies, depending on whether they are descended from marine ancestors or a genetic line selected over generations. The most tolerant biological compartments are adult freshwater fishes, followed by macroinvertebrates. Freshwater algae, aquatic plants and microinvertebrate seem to be less tolerant. Diatoms are particularly sensitive to water mineralization and could react to a small increase in salinity as low as 0.1 g/l. Species from these freshwater groups rarely tolerate levels above 3 g/l, which is the commonly accepted boundary between fresh and brackish waters.

Indicators of increased salinity potentially exist, but they are based on case-by-case interpretation of data collected on the river as there are no standard methods or these are difficult to apply. The most successful methods to diagnose salinization are based on the analysis of diatom communities. Macroinvertebrates are the most sensitive group as an indicator for animals.

Conclusions and new research directions

The salinity of the River Moselle downstream of releases from soda production exceeds 1 g/l, the threshold for observable effects on biotic communities. Salinization of the Moselle is unusual in at least two ways. The first is that the overall increase in salinity is not solely due to chlorides, even though they make up a large share. The second is that the dependency of salinity values on flow is fairly weak in the context of seasonal variability, thanks to the regulation of anthropogenic salt inputs. If regulation of releases from the soda industry is based on limits for chlorides or total salinity, it seems important from an ecological point of view to limit other elements such as potassium and magnesium as well. The toxicity of these ions to wildlife exceeds their quantitative share in total salinity. Limiting the release of chlorides is necessary to protect aquatic life, but it may not be sufficient. The nature of all ions involved in salinity must be taken into account.

Consequently, further studies could be devoted to two main topics. The first would consist in an annual analysis of the temporal evolution of salinity and its components along the Moselle. This would help to better understand factors that influence the variability of salinity. The second would aim to measure the impact of salinity on biological communities, making use of specific surveillance data on diatom communities and conducting ecotoxicological studies. Diatom communities could act as the sentinel to reveal the early effects of changes in water mineralization. In addition, as the ion components of the Moselle are singular, a toxicity study could help to better understand how biological communities are influenced by the ionic nature of the anthropogenic source of salts. Invertebrates represent the most appropriate compartment for this approach.