Water temperature increase in receiving waters due to the increase of imperviousness: a multidisciplinary assessment approach

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Water temperature is one of the key parameters influencing the chemical equilibrium and development of flora and fauna in aquatic systems. An increase in temperature reduces oxygen solubility, accelerates metabolism, such as photosynthesis or the development of fish eggs, and raises the sensitivity of organisms to toxic substances, parasites and diseases. In urban areas, an increase in water temperature also may result in an increase in toxicity from ammonia discharging from combined sewer overflows [(VSA 2007).
There are numerous causes of temperature changes in receiving waters. Natural causes can include climate (daily, seasonal and long-term changes) (Hari et al. 2006), the presence or absence of near-stream shading, the morphological conditions of the receiving waters or groundwater discharge into the aquatic system. Anthropogenic causes can include discharge from hydro-electric power stations with storage lakes (sudden reservoir drainage causes a sudden temperature drop in the receiving water), discharge of industrial cooling water (which usually heats the receiving water), and urban stormwater discharge during a rain event (Rossi & Hari 2007; Margot 2008). This discharge of urban stormwater during a rain event can constitute a temperature problem for receiving waters. In urban areas, this thermal boost is related to the flow regime, the thermal and physical properties of urban surfaces and the removal of riparian vegetation along urban watercourses. These factors increase the amount of thermal energy in urban receiving waters and may lead, particularly in summer, to a short-term spike in the receiving water temperature at the beginning of a rain event. In fact, sealed asphalt surfaces or roofs can reach extremely high temperatures (> 60°C) during extended periods of good weather. A simultaneously low water discharge rate in the receiving waters increases the potentially dangerous thermal effect of the stormwater discharge to indigenous aquatic biota.
In the 1990s, an alarming decline in the catch of brown trout (*Salmo trutta fario L.*) in rivers and streams occurred in Western Europe, including Switzerland (Burkhardt-Holm et al. 2002). The climatic temperature increase is considered to be one of the main driving forces of this decline (Hari et al. 2006). In addition to climatic change, the progressive increase in the area of impervious surfaces (e.g. pavement) caused by urban development leads to stormwater reaching aquatic systems more rapidly, resulting in higher in-stream temperatures than in the past. Swiss anglers suspect that urban stormwater discharge into rivers and streams during rain events may harm the development of certain fish species.

Since legal temperature limits are calculated only over a long-term discharge period (≥ year), they cannot be applied to short-term alterations such as those expected following rain events, thus creating a legal loophole.
This question will be addressed with in this paper. Thresholds are proposed for sensitive habitats during a rain event as assessment criteria to protect the fish in the receiving waters from thermal harm. The thresholds are based on the temperature requirements of brown trout, one of the most important fish native to Swiss rivers and streams. A multidisciplinary assessment approach, including hydrological, physical, biological and ecotoxicological processes will be presented and subsequently validated through the presentation of different case studies of differently sealed surfaces in Switzerland.

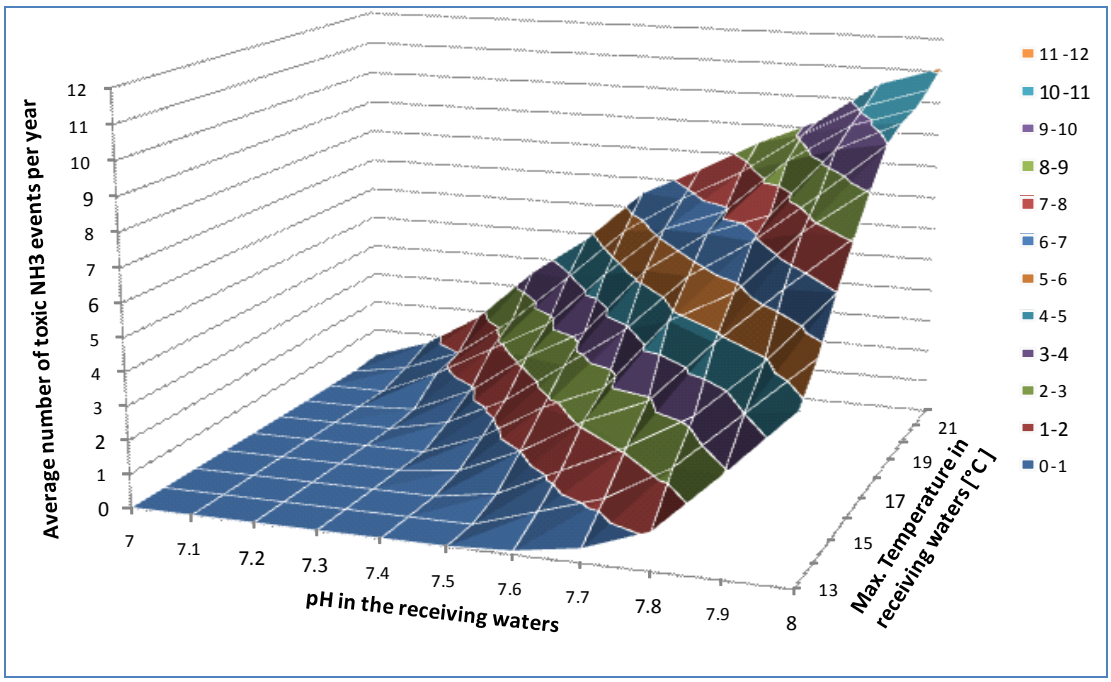

Figure 1. Example of the influence of temperature and pH on the number of critical ammonia toxicity events per year in a stream (Margot, 2008). In Switzerland, one critical event in 5 years is tolerated (VSA 2007).

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