Abstract

Climate change increased rainfall and increased risk of rising groundwater levels in urban areas and its impact on the pollution of urban water has received little attention until now. As well has the impact from natural hazards on the distribution and spreading of pollutant received little attention. This short paper for the NORDROCS 2012 conference summarises the result from two projects that aims to highlight these issues.

Introduction

There is more or less a consensus on global temperature increase and regional changes in precipitation however the likely impact on water quality is still quite uncertain. Changes in flow regimes will influence the hydromorphology (the evolution of a hydrologic system), having impact on soil and water chemistry as well as on ecology, but also on geotechnical engineering due to the impact on slope stability from flow induced erosion and soil saturation from rain.

Consequences of climate change on urban areas and water quality have therefore been a concern in many projects (see for example the EU-projects AquaTerra, ACQWA, CLIMAWAT, REFRESH, SAWA, see also papers by for example Delpla et al., 2009; Matthies et al., 2006; Praskievicz and Chang, 2009; Rehana and Mujumdar, 2011; Simonis, 2011; Whitehead et al., 2009). Nevertheless, only a few studies explicitly consider water quality impacts in urban areas under climate variability and change, especially with concern to micro-pollutants. Even fewer studies have paid attention to the risk for mobilization and mass transport of pollutants into surface water from natural hazard like landslides (Göransson et al, 2012). There are indications that the changes in climate may increase the frequency of both flooding and landslides in areas experiencing precipitation increase (e.g. Dixon and Brook, 2007; Huggel et al., 2012; Kundzewicz et al. 2009; Matthias and Lambert, 2009), and that unsustainable development in many countries is one of the causes behind the increase in landslide frequency that is already seen (e.g. Roslee et al., 2012; Catani et al., 2011)

Measurement of precipitation from 1981-2010 in the Gothenburg area, SW Sweden, shows an increase in precipitation both regarding total rainfall but also regarding intensity (Haeger-Eugensson and Tang, in prep.). The increase in rainwater can also be linked to an increase in discharge in the rivers at least since the start of the measurements in 1990 and climate models has forecasted an increased precipitation in the Gothenburg area both regarding total rain fall and intensity in future (Haeger-Eugensson and Tang, in prep.).
This paper presents the results from two projects; one addressing the changes in urban surface water quality from rain, and the other addressing the mobilization of pollutants from landslides. The study site is the Gothenburg area with main river Göta älv. The river Göta älv and its tributaries Säveån and Mölndalsån debouch into the harbour of Gothenburg. All three rivers are impacted by urban development and hide legacies from the past. They also suffer from flooding, bank erosion and landslides, influencing the water quality in the rivers and in the estuary of Gothenburg.

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Materials and Methods

The first project is one part of the EU Interreg IVB North Sea Program project diPol (Impact of Climate Change on the Quality of Urban and Coastal Waters - Diffuse Pollution). It includes climate related river water sampling in the Gothenburg area for the investigation of the significance of saturated and wet urban soils and land surfaces to the river water quality. In this study, we wanted to avoid first flush sampling as it is known to peak concentrations, but rather wanted to catch the impact from water saturated ground. Sampling was done for a dry and a wet period in the summer of 2010. Additional sampling was carried out for a spring flood event. The results were then analysed and discussed in relation to climate change and rivers as contaminant carrier, and possible consequences for the urban and coastal waters. The pollution contribution from rivers was also assessed in relation to other pathways (urban groundwater, surface run off, stormwater flow, air deposition). The results were compared and discussed in relation to other methodologies used to find answers on climate change driven mobilization and transport of contaminants, such as first flush sampling and specific rain event sampling. A strategy to maintain or improve the urban coastal water quality was finally evolved through a system analysis with stakeholder experience. Diffuse and point sources were addressed and the precarious landslide situation for the study site was acknowledge.

In the second project, an analytical approach was taken to simulate the sediment transport released from landslide into rivers. The studied landslide took place in an industrialized area and encompassed three distinct non-Gaussian peaks in the online turbidity recordings at a freshwater intake downstream the slide are. The analytical solution was then used to estimate possible contaminant load to surface waters from such event. The work was preceded by a conceptualization of governing processes for mobilization (Göransson et al., 2009), and is followed by a probabilistic risk estimation method (Göransson and Norrman, in prep.).

Results

The main findings from this study indicates on a relation between a short term increase in precipitation (wet periods) and an increase in micro pollutant transport with increasing concentrations of total PAH, Cd, Cr, Hg, Pb and Zn from diffuse sources to the river Göta älv and its tributaries, especially for the particulate phase (Frogner-Kockum et al., in prep). Also the highest concentration of suspended sediments was found for the wet period. The lowest concentration, both for micro-pollutants and suspended sediment, seemed to vary between the dry period and the spring flood event. The overall conclusion from the study was that a long term prediction could be drawn of a future climate change effect with an increased transport of micro-pollutants in the Gothenburg area (Frogner-Kockum et al., in prep.).
The contribution of pollutant from the rivers and streams to the estuary were compared with the contribution from stormwater (surface run-off), treated sewage water outflow, groundwater outflow and air deposition. Although rivers are large contributor to the pollution load in estuaries because of the large water volume they carry, it could be concluded that stormwater is of major concern (Rihm and Göransson, in prep.; Stevens et al., in prep.).

However, precipitation does not only influence the transport of pollutants, it also influences the soil parameters, increasing soil pore water pressure and enhances erosion, thus affecting slope stability. Adjacent to the river Göta älv, several potential contaminated sites have been found to be located on ground with unsatisfied slope stability (Göransson et al., 2009; Helgesson and Rihm, 2011). Applying classical analytical solutions to the advection-dispersion equation for describing the effects of a landslide into surface water yields realistic predictions of the resulting concentration distribution in the river, if the initial conditions at the landslide site are known. Figure 1a shows the non-Gaussian and strongly skewed suspended sediment peaks (as turbidity readings) at the fresh water intake 2.6 km downstream the landslide under study, while figure 1b shows the analytical solutions to the first suspended sediment peak. It could be estimated that a slide of this type (rotational slide in clayey soil) and size (small) released additional sediment that correspond to about 1-2% of the annual load. The result also indicated that the event caused an additional release of metals corresponding to 0.1-0.5% of the annual load. Most of the fraction of material displaced by a landslide of this type remains hence at the site in the river, leaving uncovered contaminants exposed to erosion. Nevertheless, a landslide of larger size or looser cohesion could release a significant amount of pollutants.

![Fig. 1a. Measurement of turbidity at the freshwater intake 2.6 km downstream landslide.](image)
![Fig. 1b. Calculated and measured variation in suspended sediment concentration for the first event.](image)

**Discussion**

The result from the climate related surface water sampling indicate that saturated soil and surface run-off leaches more pollutants to the surface water than is diluted by river flow volume (Frogner-Kockum et al., in prep.). This was also found for rain event sampling and first flush sampling that was carried out at two other sites within the diPol project (Sharma et al., in prep.; Breedveld and Hansen, in prep.). The variation in suspended sediment concentration with the events seemed to be a combination of flow and run off from the surroundings, meaning that flow and run off alone does not govern suspended sediment concentration in the surface water, but a combination of the two.

Based on the results and through stakeholder experience, a good strategy to prevent from the continuously pollution from urban areas to the coast is to take further measures to reduce the pollutants in the stormwater. As the climate change scenarios for the study site indicates
more rain and as most contaminants are mobilised and transported with water, actions must be taken to reduce the spreading of contaminating substances to sensitive areas, like estuaries and coastal zones. In addition to the continuously pollution from diffuse sources, climate also triggers natural hazards. Events of low frequency but high magnitude can therefore be of vast importance and bring the ecosystem over the tipping point. In this paper such event has been described as a landslide that carries pollutants from a contaminated site to surface water. A landslide can however also cause damming and flooding of upstream located contaminated sites and cause erosion of contaminated river banks from landslide generated impulse waves.

To summarize, there is an interaction between aquatic and terrestrial systems that can only be explored using integrated strategies (or models) that includes climate, land use, lakes, rivers and coastal waters. With the objective of NORDROCS in mind, contaminated sites should hence be assessed in a larger perspective and at a catchment scale, taking into account driving variables such as precipitation and temperature but also land use planning (regional growth, exploitation and demographic changes).

References

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