DiPol

WP "Risk analysis"

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1. Background

Expected climatic changes (CC) will lead to more extreme discharges of rivers, extensive rainfalls in the watershed and increased seawater levels. Along with the obvious effect on water quantity, these developments will have consequences for the water quality in terms of nutrients and contaminants that are flushed from streets and agricultural areas into rivers and transported to the coastal areas impacting bordering countries. DiPol aims to collect knowledge on the impact of CC on water quality, to communicate and raise awareness towards this knowledge, to improve the ability of decision makers to counteract these impacts on local and international level, and to facilitate public participation herein.

In the “Risk analysis" work package, 4 case studies have been investigated that are located at different positions within the river-coast continuum (Figure 1). Accordingly they will be affected to a different extent from continental impacts of CC (Increase of rainfall, rising groundwater level, increased frequency of high and low river discharge) and coastal ones (sea level increase, storm surges). Existing data have been gathered for the 4 sites, processes modelled, and event-based sampling surveys have been carried out. The influence of river emissions on coastal water quality has been modelled. Risks from measured emissions to the local sites, river mouths and coastal environment have been evaluated.

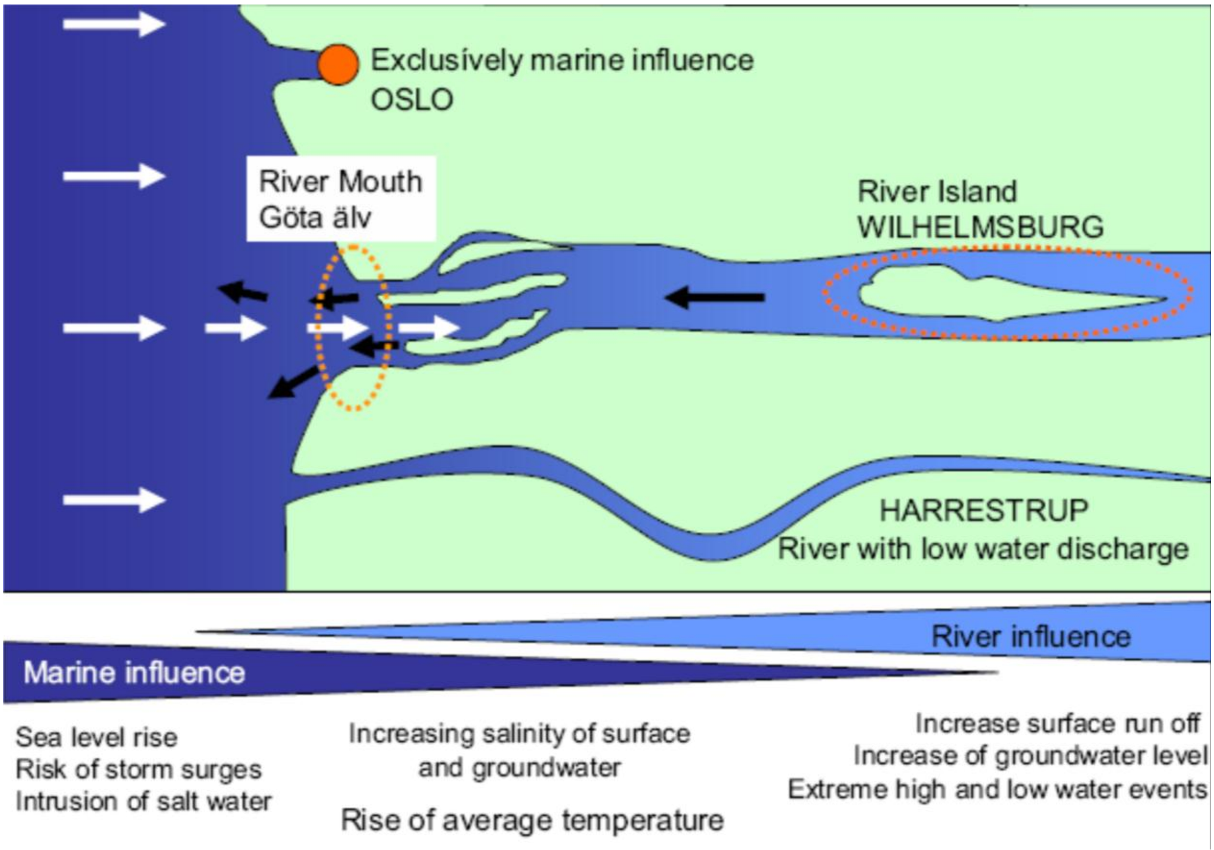

Fig. 1: Strategic location of the 4 case study sites within the river continuum.

The 4 case study sites are:

I. **Inner Oslo-Fjord**, Norway, example for Northern European cities, located at fjords, only marine influence. Challenges: Urban water run-off, coastal sediment re-suspension.
II. **Göta älv near Gothenburg**, Sweden, example for coastal cities located at the river mouth, marine and freshwater influence. Challenges: Surface and groundwater level, high river water discharges, urban-water run-off.
III. **River island Wilhelmsburg in Hamburg**, Germany, example for urban areas influenced more by large rivers than by marine waters. Challenges: urban water run-off, river floods, storm surges, rising groundwater level.
IV. **Harrestrup River and Kalveboderne Lagoon near Kopenhagen**, Denmark, example for urban environments at small rivers with little marine influence. Challenge: Urban water run-off.

In addition a model (SCREMOTOX) has been developed to evaluate the impact on contaminants from run-off on the receiving marine environment of the North Sea.

2. Inner Oslo-Fjord, Norwegian case study

The aim of the study has been to investigate the impact of Climate Change on the water quality in rivers influenced by urban run-off. These rivers are running into and the harbour area in Oslo. The river Akerselva has been a model river in the study. The water quality in Akerselva river has been investigated by event based sampling surveys under snowmelting, high and low water waterflow and after extensive rainfall. Results from the surveys have been evaluated in relation to monitoring data from Oslo municipality on the river water quality, thereby complementing the existing data set. The sampling events clearly showed a higher load of contaminants during snowmelting. Particularly the load of suspended matter was elevated as well as the level of particle bound contaminants (PAH, Cu, Pb) were increasing (Figure 2). This increased contamination level is reflected by a higher response in toxicity test of the suspended matter. During rain events, dilution will result in reduced contaminant levels and an improved water quality. in However, the total contaminant load transported to the fjord and harbour area can increase due to the large amount of river water run-off. The results documented the importance of rain events for the concentration of suspended matter (Figure 3), as well as the concentration of PAH, PCB and other organic compounds in suspended matter. The load of contaminants transported into the harbour area during the different climatic events will form the basis to compare the contribution from river run-off to other sources in the inner Oslofjord. Waste water treatment is identified as another major contributor to contamination of the fjord during extensive rain events. This forms the basis for the relative risk model developed in the WP “SIMACLIM”.

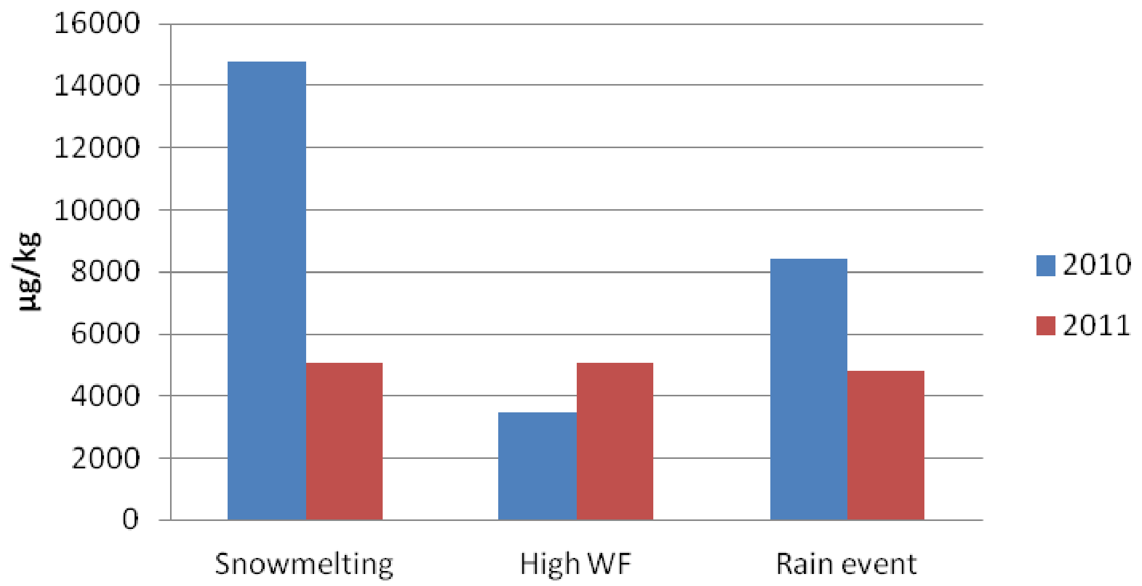

Fig. 2: PAH levels in suspended matter of the river Akerselva during different climatic events.

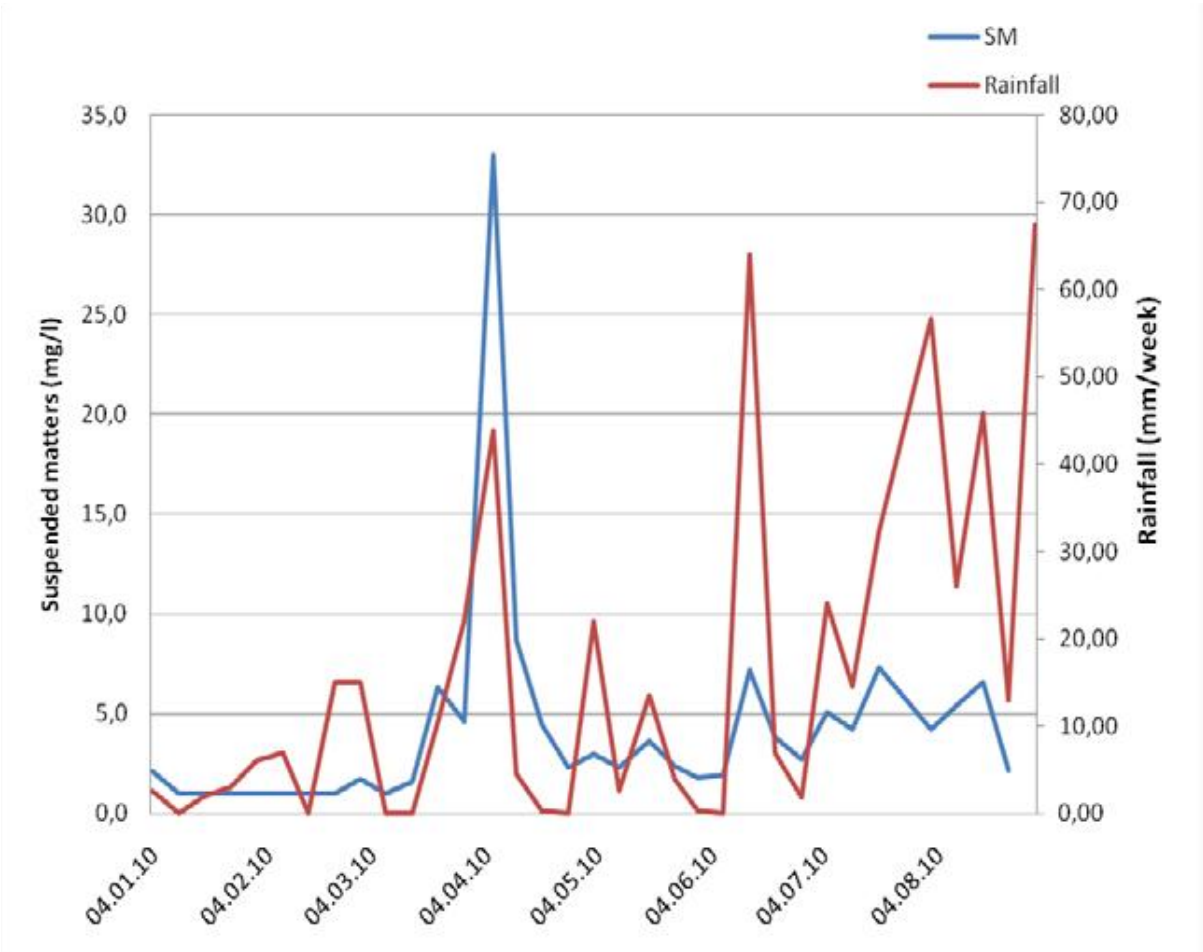

Fig. 3: Relation between rainfall and suspended matter load in the river Akerselva.

3. Göta älv near Gothenburg, Swedish case study

The aim of this study was to investigate the impact of dry and wet weather on variation of water quality in urban coastal rivers, and to link climate changes to possible changes in pollution load to the estuary. The theory is that not only single rain events or short extreme meteorological events have impact on water quality but also the duration in dry and wet weather - flooding and droughts. Thus, we hypothesize that well-wetted (saturated) urban soils, well-wetted land surfaces, and high discharges, increases the pollution concentration for micro pollutants that have large adsorption capacity to colloids, organic and inorganic particles. The objective was to sample during spring flood, and during a dry and a wet period under the same season, in order to estimate the importance of climate to water quality variations. Lead, cadmium, chromium, mercury and PAH was determined as the major environmental indicators for micro pollution in this area, beside suspended matter that also was analysed. Our strategy was to sample at multiple watercourses to evaluate relative importance and variation.

The results of this study show a relation between a short term increase in precipitation (wet periods) and an increase in micro pollutant transport with increasing concentrations of total PAH:s, Hg, Pb, Cd and Cr from diffuse sources to the Göta River and its tributaries during wet periods and spring floods (compared to dry periods). It was found that transport of suspended sediments dominated during the wet period influencing the transport of particle bound contaminants. The results indicate that a wetted soil leaches more micro-pollutant to the rivers than is diluted by a increased run-off, and that streams running through urbanized areas functions as important contaminant carriers to the sea. Rain statistics for the Göteborg area clearly indicate an increase in precipitation and rain events. Also climate models have forecasted that the precipitation still will increase in future in the Gothenburg area both regarding total rain fall and intensity. From these data it is concluded that a long term prediction could be drawn of a future climate change effect with an increased transport of micro pollutants in the Göteborg area.

Urban groundwater affects urban surface and coastal waters and can influence the Göta River estuary. Analyses of groundwater wells, and drainage water (storm water pipes during periods with little or no precipitation) indicate that leaching of pollutants from the filling material in the city is not a major problem. Only for copper and arsenic the leaching is significantly higher than for natural soils surrounding Göteborg. The main contribution of metals and PAH to the Göta River from the city seems to emanate from the stormwater (Figure 4 and 5).

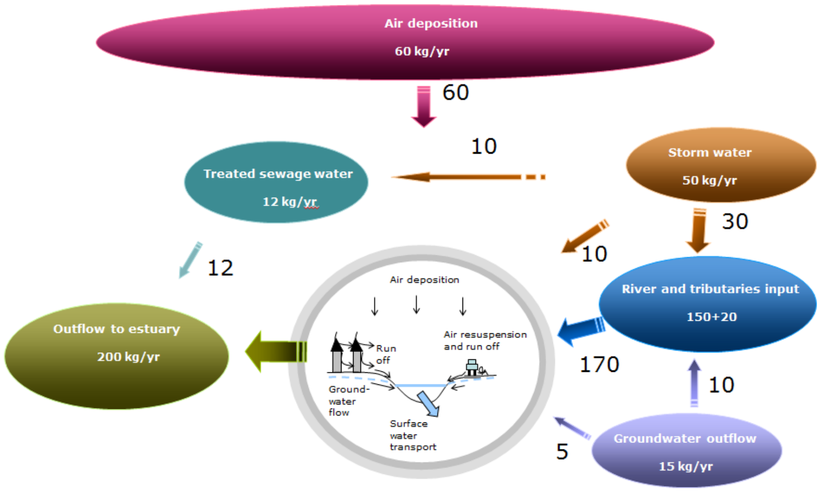

Fig. 4: Contaminant load of PAH to the Göta älv estuary.

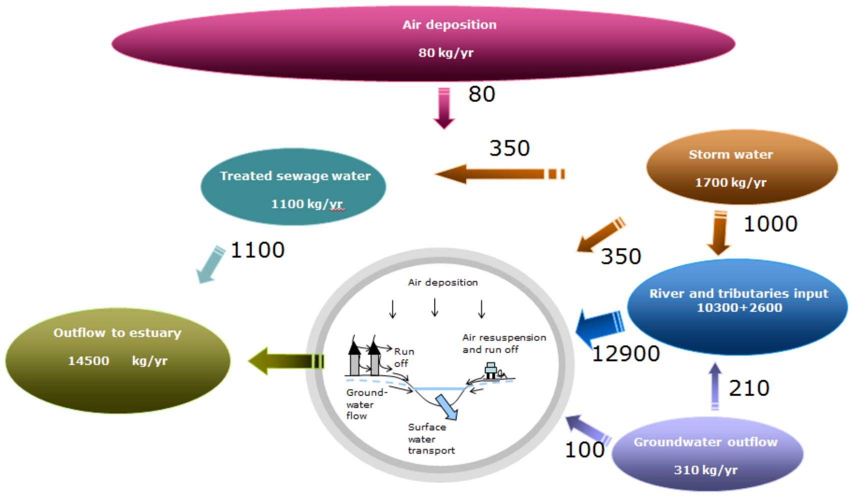

Fig. 5: Contaminant load of Copper to the Göta älv estuary.

4. River island Wilhelmsburg in Hamburg, German case study

Projections on climatic changes for the Elbe estuary based on model results from Hagemann and Jacob (2006) suggest an increase in winter precipitation for the Elbe drainage area in the Czech Republic and partly for the watersheds of the Elbe-tributaries of Mulde and Saale by 50 % in 2071-2100 compared with 1961-90. High precipitation intensities of more than 5 mm/day could increase already in the decade 2020 to 2029 by more than 5 % (Jakob and Bülow, 2005). Whether this will result in an increased frequency of high discharges is still uncertain (see www.Kliwas.de) but of high importance, as flood surges in the Elbe have been known to carry approximately up to 70% of the annual contaminant load downstream. As 3 exceptionally high flood events occurred in the Elbe Watershed in the years 2002, 2006 and 2011, the Elbe case study focused on the impact of flood events on the contamination of ecologically important mud flats in the Elbe estuary, depending on the discharge level. Increased precipitation in Hamburg itself may lead to a high surface run-off, carrying contaminants and pathogens from industrial and agricultural areas to urban waters and from there to the Elbe River. Water samples and samples of suspended matter and sediment have been collected around the river island Wilhelmsburg, in order to quantify the potential risk for urban waters and for the Elbe estuary. Another climatic change is the increase of sunshine duration and intensity (Gerstengarbe and Werner 2005), going along with increased UV exposure. This may affect sediment-bound contaminants in mud flats regarding their concentration, formation of metabolites and toxicity.

Major results:

• High flood events (> HQ20) seem to cause increased contaminant concentrations (HM and organics) of mobile sediments in mudflats (freshwater and marine)

• This increased contamination is not reflected by ecotoxicity. The question still needs to be answered, whether this is due to a low bioavailability of historic contaminants or by low sensitivity of bioassay responses.

• Increased UV-exposure of mud flat sediments from the nature reserve in Heuckenlock leads to an increase of toxicity of sediment elutriates in one bioassay.

• Suspended matter in urban canals in W'burg shows partly very high contamination with the level and kind of contamination depending on sources within the drainage area. The number of dissolved organic contaminants in the urban waters is high and could in part be assigned to specific land uses No connection has been established yet to precipitation in the sampling period.

• E.coli as indicator of anthropogenic emissions have only been found in high concentrations in one sampling area in Wihelmsburg close to a hospital. Even during high discharge from the combined sewage overflows, the risk for the Elbe river remains low due to the high dilution.

• For the same reason, also the impact of urban waters on coastal waters is very low.

5. Harrestrup River and Kalveboderne Lagoon near Kopenhagen, Danish case study

The activities in the Harrestrup Stream Case Site, aims at identifying impacts from storm water (separate and combined sewer discharged) and at suggesting measures to reduce adverse consequences of climatic changes for the quality of a steam and a coastal area. The study has focused on function of rain water storage basins, pollution from paved urban areas, and pollution from overflow on sewage system during intensive rain event and impact hereof in the southern part of Copenhagen harbour. The function of rain water storage basins have been studied in Bassin K , Ejby Bog and Ejby Vaenge Basin. The pollution load and impact of climate change on impact from storm water overflow on the combined sewage system have been studies at discharge locations in the lower Harrestrup stream and by modelling impact in the stream and the harbour. A series of measurement campaigns have been performed, which characterized rainwater to and from the storage basins. A modelling tool was developed that can simulate how the concentration of contaminants varies during rainwater inflow and when water passes the basin. The studies show that water quality in the inlet to the pond varies depending on rainfall patterns and dry weather periods. Results from sampling in the inlet and outlet of the basin were used for calibration of the model. This model was used for comparison of different scenarios for storm water management. The model can assist in taking the right decisions to improve water quality in the outlet from the basin and which goes into Harrestrup Stream. The potential effect of climate changes was evaluated by applying two 100-year synthetic rain series, representing the current climate conditions and expected changes due to climate change, respectively. The measurements from the current system showed that the extreme rain events are important for high particulate metal concentrations and for the estimation of the total load discharged from the catchment. The model results suggest that the climate change scenario, with predicted increase in the extreme events, can result in increased particulate concentrations in runoff from the catchment. The discharges from the basins are in general considered to be of a quality that does not contribute to degradation of water quality in Harrestrup steam. During heavy rain the sewer capacity can be exceeded and raw sewage can be discharged into the steam causing heavy pollution of bacteria, oxygen consuming substances, nutrients and other environmental harmful substances. The frequency of such events is expected to increase due to climate changes. Several sampling campaign were performed during such events with focus on the load of bacteria, organic substance and environmental harmful organic substances (priority substances) as well as heavy metals to the stream. The first flush wash out of bacteria (high concentration followed by a decreased level) during storm water overflow was characterized. Scenario simulation with an existing dynamic model for Harrestrup Stream showed that significant increase of the impact in the stream and the downstream harbour areas can be expected as a result of climate. The study further more showed that the problem can be handled by introducing very big storage basins in the catchment. However, this will require high investments. Alternative economically much more attractive solutions exists, which include alternative local handling of rain water within the catchment.

6. Coastal contaminant transport (SCREMOTOX model)

The objectives of this study was to: 1) estimate the relative contribution of diffuse sources of pollution to coastal water quality on the scale of the North Sea, and (2) to show the impact of climate change in this context. This North Sea wide assessment (NSA) is based on data, information and model results developed for the North Sea. It is carried out in addition to the four local case studies (LCS) described earlier. It should be noted that there is a scale difference between the LCSs and the NSA (both with respect to spatial and temporal scales). The North Sea wide assessment has been supported by a mathematical water quality model called Scremotox, applied to the wider North Sea area. This model uses information about the residual currents and about the emissions of defined chemicals to calculate approximate concentrations in the North Sea water. On top, the model quantifies the relative contribution of each emission source to the local concentrations. Figure 6 provides an example for Benzo[a]pyrene (year 2005). The assessment of the impact of climate change on diffuse pollution on the scale of the North Sea has been carried out by a methodology outlined below. The focus has mostly been on diffuse pollution from particle bound contaminants carried by the rivers draining into the North Sea. The assessment has as far as possible been made in a quantitative way, using the outcome from a Global Hydrological Model driven by different Global Climate Models, and a database of the measured quality of suspended solids as a function of the river flow.

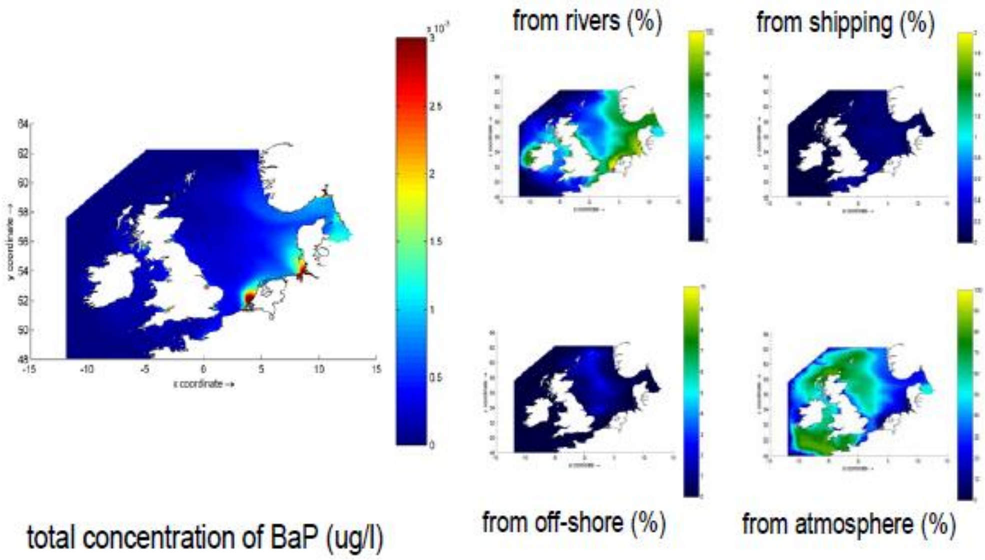

Fig. 6: Simulated concentrations of Benzo[a]pyrene in the North Sea, based on the available emission data for 2005 (left) and the relative contribution of different emission types to the local concentrations (right).

7. Discussion

The results from the risk analyses carried out at the 4 case study sites as well as the North Sea wide assessment show that there are reasons to be conscious of a possible Climate Change induced increase of (sorbed) chemicals run-off from rivers into the sea. However, no solid evidence of this process presently exists for the North Sea, taking into consideration the uncertainty in the forecasted impacts of climate change on the river hydrology, on the river sedimentology and the changes in the estuaries along the North Sea's coastal zone (Figure 7). The increase of (sorbed) chemicals run-off from rivers into the sea as found at the case study sites is associated with extreme events. However this does not necessarily lead to a major change in the average contaminant load to the North Sea. More "event" water quality data are needed to improve insights into these processes. Monitoring long term changes of the sediment and biota quality in coastal lagoons could be a feasible way to implicitly measure the possible impact from extreme events on the long-term development of the environmental quality.

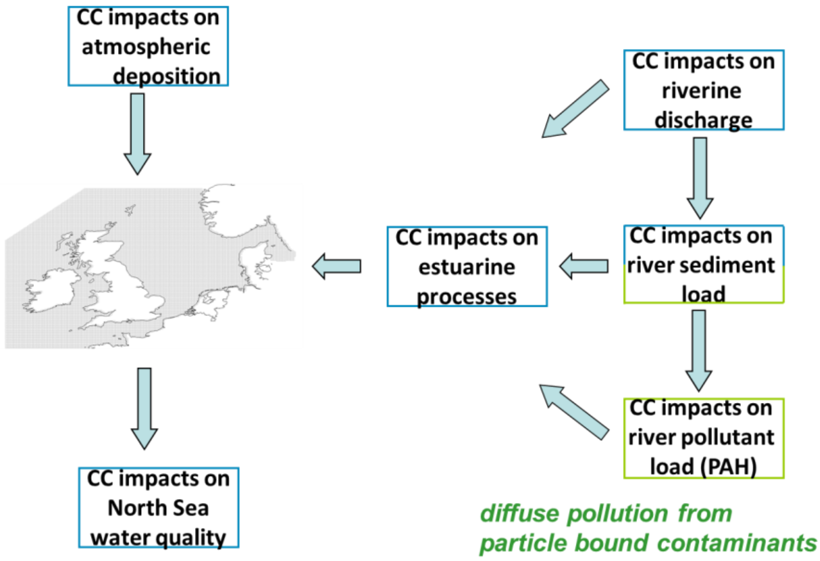

Fig. 7: Influence of climate change on contaminant transport processes to the North Sea.