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Effects of a sewage treatment plant outlet pipe extension on the distribution of contaminants in the sediments of the Bay of Vidy, Lake Geneva, Switzerland

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Abstract

In 2001, the municipality of Lausanne extended the outlet pipe of the sewage treatment plant into the Bay of Vidy (Lake Geneva, Switzerland) as a measure to reduce bacterial water pollution and sediment contamination close to the lake beaches. The aim of the present study was to assess the impact of this measure. Lake bottom sediments were collected and analyzed for grain size, organic matter, organic carbon, nitrogen, phosphorus, heavy metals and hydrophobic organic compounds to evaluate their concentration and spatial distribution. Our results demonstrate that, compared to results obtained before the outlet pipe prolongation, the surface area of highly contaminated sediments was reduced by one third after the pipe extension. However, contaminant concentrations are still high and the accumulation of pollutants may represent a significant source of toxicity for benthic organisms. One concludes that contaminant reduction at the source will be necessary for a further improvement.

Keywords: Heavy metals; Lake Geneva; Micropollutants; Sediments; Sewage treatment plant

1. Introduction

Sediment contamination is usually due to inorganic and organic compounds including heavy metals (HMs) and hydrophobic organic compounds (HOCs), such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs). Anthropogenic activities as well as urban effluent water constitute the main sources of aquatic environment contamination. The contamination of sediments by inorganic and organic micro-pollutants is a concern and unsolved problem in numerous coastal ecosystems, estuaries, lakes and rivers all over the world (Förstner and Wittmann, 1979; Schwarzenbach et al., 2006). Sediment contamination might cause potential irreversible adverse effects to ecosystems and also pose human health risks. HMs cause serious environmental risks and their removal from wastewater or accumulation in sediments should be examined extensively (e.g., Wang et al., 2004; Wildi et al., 2004). The main environmental risk is remobilization of the contaminants and their return to the hydrosphere either by sediment re-suspension or by infiltration into the groundwater (Wildi et al., 2004). The modification of environmental conditions such as pH, redox potential, bacterial activities, or ligand concentration can lead to the release of HMs from the sediment to the water column and increase their bioavailability (Cantwell et al., 2002; Lors et al., 2004). Therefore, polluted sediments also represent an important source of contamination for fresh water organisms (Kang et al., 2000; Verweij et al., 2004).

HOCs, including PAHs, PCBs and OCPs have been identified as environmental pollutants in all environmental

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compartments (Wu et al., 1999). Due to their high persistence and low solubility in water, HOCs can accumulate in sediments.

Lake Geneva is the largest freshwater reservoir of Western Europe with a surface area of 580.1 km^2, a volume of 89 km^3 and a maximum depth of 309.7 m. It is a warm monomictic temperate lake, with early spring overturn not occurring every year. The lake was considered as eutrophic in the 70s and 80s, but is now mesotrophic after drastic reduction of phosphorus inputs (Dorioz et al., 1998). General surveys of the metal and nutriment content of the lake sediments have been performed in 1978, 1982 and 1988 (see Arbouille et al., 1989). Organic and metallic pollutants have been recently studied in water, mussels and fish by Corvi et al. (2005). In general concentrations are low and compliant with Swiss regulations.

Approximately 700,000 people are supplied by water from Lake Geneva. The city and agglomeration of Lausanne, located on the lake shore, generates large volumes of wastewater. A sewage treatment plant (STP) was built in 1964 for 220,000 equivalent-inhabitants (approx. 412,000 equivalent-inhabitants at present time) at the location of Vidy, on the northern lake shore (Fig. 1). Initially consisting of a two-stage treatment plant (mechanical and biological treatments), it has been equipped since 1971 with a chemical stage. In this stage, added ferric chloride ($FeCl_3$) precipitates with phosphate to form insoluble complexes which are removed by decantation. In 1976, the STP was expanded and the efficiency of wastewater treatment was improved. From 1964 to 2001, the STP effluents were discharged into the lake about 300 m from the lakeshore, at 15 m water depth. As a result, the shallow Bay of Vidy is the most contaminated area of Lake Geneva (Loizeau et al., 2004; Pardos et al., 2004; Wildi et al., 2004). Published data demonstrate the accumulation of contaminants close to a city recreational area on the shore and its related ecological impact and health risks, mainly due to the presence of faecal bacteria and of sediment contamination. In 2001, the Lausanne municipal authorities decided the extension of the STP outlet pipe discharge to a distance of 700 m from the shore, at 35 m water depth. This decision was based on the following assumptions:

(a) Bacterial contamination of the shore is due to the backflow of contaminated water from the STP outlet to the shore.
(b) The accumulation of contaminated sediments in the bay is mainly due to local circular lake currents, retaining water masses and suspensions within the bay, isolated from the zone concerned by the main lake currents.

The rational for the prolongation of the STP outlet pipe discharge system was (1) to reduce in a significant way the concentration of faecal bacteria in the surface water (Goldscheider et al., 2007) and (2) to reduce the accumulation of pollutants in sediments close to the shore. Also, no measure to reduce contaminant concentration at the source, that means in the STP, was considered at that time.

The objective of the present study was to assess the quality of bottom sediments of the Bay of Vidy after the prolongation of the outlet pipe of the sewage treatment plant in 2001. This assessment is based on the determination of concentrations and spatial distribution of organic matter and heavy metals (Cu, Cd, As, Fe, Cr, Ni, Zn, Pb, Ag, Hg) in bottom sediment samples from 25 sites of the bay. The hydrophobic organic compounds (PAHs, PCBs, OCPs) levels in the sediments sampled from 3 sites close to the present STP outlet pipe discharge location were determined to examine the direct effect on the nearby sediments at the STP outlet.

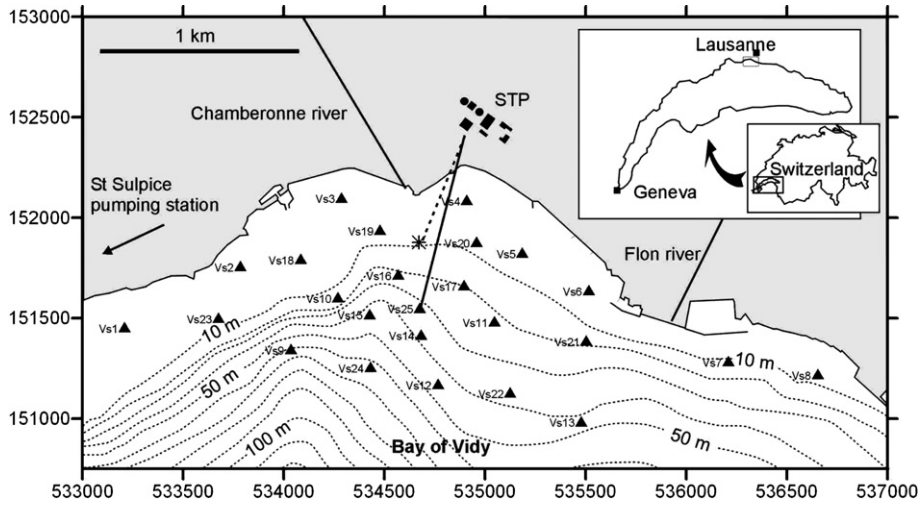

Fig. 1. Location map of the study area, sample sites (▲ noticed Vs): * and Vs25 represent the points of outlet pipe of sewage treatment plant discharge in the bay before and after 2001, respectively.