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The contribution of urban runoff to organic contaminant levels in harbour sediments near two Norwegian cities

Gerard Cornelissen [a,b], Arne Pettersen [a,*], Elisabeth Nesse [a,1], Espen Eek [a], Aud Helland [c,2], Gijs D. Breedveld [a]

[a] Department of Environmental Engineering, Norwegian Geotechnical Institute (NGI), P.O. Box 3930, Ullevål Stadion, N-0806 Oslo, Norway
[b] Department of Applied Environmental Sciences (ITM), Stockholm University, 10691 Stockholm, Sweden
[c] Norwegian Institute for Water Research (NIVA), P.O. Box 173 Kjelsås, N-0411 Oslo, Norway

Abstract

The main aim of the present study was to compare the quality of particle emissions (urban runoff and settling particles in rivers and harbours) to the quality of top-layer bed sediments, for two Norwegian harbours (Oslo and Drammen). A sub-aim was to investigate whether non-industrial urban runoff contributed to the organotin load of sediments, apart from leaching from ship hulls. Time-integrated samples of stormwater runoff were obtained in an innovative manner, by sampling man-holes in the stormwater system. Settling particles were sampled with sediment traps. The study focused on PAHs, PCBs and organotin compounds.

Contaminant levels were generally a factor of 2–10 (PAHs) and 3–30 (TBT) lower in emitted riverine and runoff particles than in top-layer bed sediments, except for PCBs in Oslo harbour (only 20–30% lower). Significant levels of tributyltin (TBT; median 140 μg/kg) were shown in runoff particles, showing that TBT can also be emitted via urban sources, since the sampled man-holes were not in areas where dry-docking activities take place. Possible land-based TBT sources include long-lasting house paint and use of TBT as PVC stabilizer and timber preservative.

Since there are ongoing emissions into the two studied harbour areas, it is concluded that the addition of an actively sorbing capping material such as activated carbon might be the best remediation alternative.

Keywords: Urban runoff; Sediment; Organotins; PAH; PCB

1. Introduction

Organotin compounds, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) are among the compounds that frequently exceed quality guidelines in contaminated marine sediments. Of the organotin compounds, tributyltin (TBT) is highly toxic, but also monobutyltin (MBT), dibutyltin (DBT) as well as phenyltins and octyltins are of environmental concern (Hoch, 2001). Leaching from ships and the application and removal of antifouling paints is often considered to be the main source of TBT to the marine environment. However, TBT is also found in pesticides used in agriculture, wood preservatives, industrial water cooling towers, and many types of PVC applications (Hoch, 2001; Peachey, 2003). So far occurrences of MBT and DBT have mainly been related to microbial and/or photochemical degradation of TBT, but recently evidence of the direct input of MBT and DBT was found, probably caused by leaching from PVC materials and house paint (Hoch, 2001). PAHs enter the marine environment via sewage outfalls, urban and industrial runoff, and atmospheric precipitation. Major sources of PAH include vehicular drippings and

* Corresponding author. Tel.: +47 22023117; fax: +47 22230448.
E-mail address: ap@ngi.no (A. Pettersen).
[1] Present address: Siv.ing Rolv A. Systad AS, Møllesvingen 2, 0854 Oslo, Norway.
[2] Present address: Rambøll Norge AS, P.O. Box 427 Skøyen, N-0213 Oslo, Norway.

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exhaust, tyre wear, petroleum spills, forest fires, coal burning, and refuse burning. PCBs have two sources: (i) PCB mixtures manufactured in past industrial activities and used as non-combustible oils in electric equipment, and (ii) by-products of combustion.

The Norwegian harbours of Oslo and Drammen are polluted by TBT, PAHs and PCBs, with TBT and benzo[a]pyrene most frequently exceeding quality standards. Emissions through point sources have been strongly reduced over the past decade. However, diffuse contaminant sources are still of concern. For PAHs and PCBs, urban runoff is one of the primary diffuse sources. For TBT it is unclear how much urban runoff contributes as a diffuse source.

The main aim of the present study was to investigate the quality of the urban runoff material in Oslo and Drammen harbours, in order to find the best remediation scenario. A sub-aim was to investigate whether non-industrial urban runoff could contribute to the organotin load of sediments, apart from leaching from ship hulls. This is to our knowledge the first study in which a thorough inventory of butyltin in stormwater particles is made. Time-integrated samples of stormwater runoff were obtained by sampling man-holes in the stormwater system. The quality of runoff particles was compared to the qualities of bed sediments as well as suspended settling particles in both the harbours and in rivers flowing into the harbours. The results will be discussed in terms of three different remediation scenarios: (i) no remediation; (ii) dredging or capping with an inert material such as sand, or (iii) amendment with an actively sorbing material such as activated carbon.

2. Materials and methods

2.1. Site description

Extensive field sampling campaigns were carried out in the year 2005, in the cities of Drammen (whole harbour area) and Oslo (eastern harbour area), Norway (Fig. 1). Sampling depths in Oslo and Drammen harbours were 6–10 m and 9–55 m, respectively. An important difference between Oslo and Drammen is the existence of a major river flowing into the harbour area: In Oslo only a small river (5 m^3/s), Akerselva, enters the area, whereas the Drammen area is the estuary of a much larger river (>20 m^3/s), Drammenselva. Oslo is a large city with a relatively modest harbour, whereas Drammen is a much smaller city with a relatively large harbour area.

2.2. Sampling of runoff material

As a result of the large seasonal variation in the runoff from paved urban areas, sampling and characterization of runoff material is challenging (Jantsch et al., 2006). A time-integrated sampling method has been developed in the current study, using the "sedimentary record" of particles deposited in the urban drainage system by taking runoff samples from man-holes and pumping stations. The purpose of man-holes in the drainage systems is in fact to collect suspended settling particles, and sampling of these suspended particles is relevant for the study of organic compounds in stormwater runoff, as for example a median 87% of PAHs was particle-bound in stormwater flowing into the Anacostia river, Washington DC, USA (Hwang and Foster, 2006). It should be noted that the relatively fine (clay) runoff particles do not settle in the man-holes, and that our results may be biased towards the larger silt and sand fractions. However, for Oslo sediment PAH contents in the sand and silt fractions were larger than those in the clay fraction (Oen et al., 2006).

Sampling locations close to the waterfront were selected to cover the expected variation in contaminant levels. All man-holes are emptied approximately every 1–2 years, so the man-hole sediment samples consist of recent urban runoff particles. All sediments in the drainage system were sampled by a 1.5-L handheld Van Veen grab sampler. Man-holes were sampled in both industrial and non-industrial locations, and also directly at a shipping wharf (M13 Drammen) and at the dry-docking facility where boats are maintained and hydroblasted (M16 Drammen). The locations are presented as the M ("man-hole") sampling stations in Fig. 1.

2.3. Settling solids

Settling sediments were sampled in inflowing rivers as well as in the harbour areas, by placing sediment traps in the rivers and their mouths, as well as in the open parts of the bays. The inflowing rivers included Akerselva (Oslo), Drammenselva and Lierelva (Drammen). The duration of the sediment trap employments was three months. In Drammen, two to three replicates were used in different seasons. Sediment traps (diameter 10 cm) consisted of two glass cylinders held vertical at constant water depth (3 m above the sediment) by a floating buoy and a mooring to the sea floor. For sample conservation, 3 mL formaldehyde was added to each cylinder. The sediment trap locations are represented in Fig. 1 as the T ("trap") locations.

2.4. Top-layer bed sediments

Sediments (S locations in Fig. 1) were sampled in industrialized harbour areas, with the exception of the northeastern part of Drammen sampling locations (Drammen S5, S11, S12) that are less industrialized. Top-layer bed sediments were obtained using a Van Veen grab corer and careful sampling of the top 0–5 cm of sediment. Deeper sediments were sampled at two stations (S1 and T5 in Oslo harbour) with a 110-mm, 600 kg gravity corer.

2.5. Organotin analysis

Analysis was carried out in accordance with DIN (German Institute for Standardization) procedure 19744 and