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Occurrence and removal of selected organic micropollutants at mechanical, chemical and advanced wastewater treatment plants in Norway

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ABSTRACT

In Norway the combined hydraulic capacity of all domestic wastewater treatment plants is relatively equally distributed between three major treatment plant types; mechanical, chemical, and combined chemical and biological. The Western coast from Lindesnes in the south to the Russian boarder in the North is dominated by mechanical treatment plants, constituting approximately 68% of the treatment capacity in that area. In the present study we report concentrations and removal efficiencies of polycyclic aromatic hydrocarbons (PAHs), nonylphenols, phthalates, polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) found in five Norwegian wastewater treatment plants (WWTPs) applying different levels of treatment. Concentrations of organic micropollutants in the influents to the WWTPs were generally in the low range of what have been reported by others for domestic wastewater in Europe and North-America. More than 90% removal could be obtained for nonylphenols, PBDEs, and the more hydrophobic 4–6 ring PAHs by chemical precipitation, however, biological treatment appeared to be necessary for efficient removal of the less lipophilic 2 and 3 ring PAHs, the medium- to short-chained nonylphenol ethoxylates and diethyl phthalate. ΣPCB_7 was removed by more than 90% by combined biological/chemical treatment, while removal efficiency by chemical treatment was not possible to estimate due to low inlet concentrations. Low or insignificant removals of PAHs, phthalates and nonylphenols with their ethoxylates were observed at the mechanical WWTP, which was in accordance with the minuscule removal of TOC.

1. Introduction

The discharge of organic matter and nutrients from Norwegian domestic wastewater treatment plants (WWTPs) is regulated on a national level to limit the total load to the different recipients, thereby minimizing potential problems with high oxygen consumption and eutrophication in the receiving waters. So far, no such regulations exist regarding organic micropollutants in the effluents from Norwegian WWTPs. Hence, the WWTPs are designed and dimensioned to achieve their prescribed removal of organic matter and nutrients, where the discharge limits are given by the sensitivity of the local recipient and the size of the particular treatment plant.

A number of studies have focused on the removal of organic micropollutants such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), nonylphenols and their ethoxylates, phthalates and linear alkylbenzene sulphonates (LAS) at WWTPs applying different types of biological treatments (McNally et al., 1998; Fauser et al., 2003; Marttinen

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et al., 2003; Blanchard et al., 2004; Katsoyiannis and Samara, 2004). Very few studies have focused on the removal efficiency of these pollutants in mechanical and chemical treatment plants. Though, chemical precipitation has been the preferred method to remove phosphorous from wastewater in Norway, also at biological WWTPs. Simple mechanical treatment, primarily for the removal of particulate matter, is dominating at small and medium sized WWTPs along the western and northern coast of Norway. Since many of the priority substances are rather lipophilic in character (octanol-water partition coefficient, $P_{ow} > 10^4$), and therefore tend to associate with the particulate matter, even mechanical treatment may contribute to the removal of these substances. On the other hand, the lack of any biological step may have significant influence on the overall removal of some of the more biodegradable compounds, such as the phthalates, LAS, some short-chained nonylphenol ethoxylates and the lighter PAHs (McNally et al., 1998; Fauser et al., 2003).

The main detrimental effects of organic micropollutants are connected to their potential acute toxicity or sub-lethal effects on the biota (Eljarat and Barceló, 2003). Toxic effects of effluent samples from WWTPs to algae, crustacean and fish have frequently been reported (Fischer et al., 1998; Schroder et al., 1991; Aguayo et al., 2004), and endocrine disruption of fish and freshwater mussels has been observed in rivers downstream biological WWTPs (Sumpter, 1995; Gagne et al., 2001; Tilton et al., 2002). The latter was primarily ascribed to the presence of oestrogenic chemicals (oestrogen mimics) in the WWTP effluents. Alkyl phenols, synthetic pharmaceutical steroids and naturally excreted steroid hormones usually represent the majority of the oestrogen-like potency (Desbrow et al., 1998; Utsunomiya, 1999; Quinn et al., 2004), though phthalates, polybrominated diphenyl ethers (PBDEs), PCBs, polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), and pesticides have also been known to show oestrogen-like potency (World Health Organization, 2002).

The objective of the present study was to investigate the occurrence of selected organic pollutants in Norwegian urban wastewater, and the capability of typical Norwegian WWTPs applying chemical or mechanical treatment for removal of these pollutants. The capability was compared to the removal efficiencies obtained in a WWTP applying more advanced combined biological and chemical treatment. Both chemical and ecotoxicological techniques were used to characterize the influent and effluent water, and to identify the changes that took place during the various treatments. In the present paper, the results and conclusions based on the chemical analysis are presented.

2. Materials and methods

2.1. WWTPs

Of the five WWTPs included in this study (see Fig. 1), one had biological treatment (anoxic and aerobic-activated sludge process) with simultaneous chemical precipitation (plant A), three had chemical treatment (plant B–D) and one had only mechanical treatment (plant E). Details from the WWTPs are shown in Table 1. The WWTPs were located in four different parts of Norway and had a rather wide variation in capacity (capacities 15 000–300 000 person equivalents, PE).

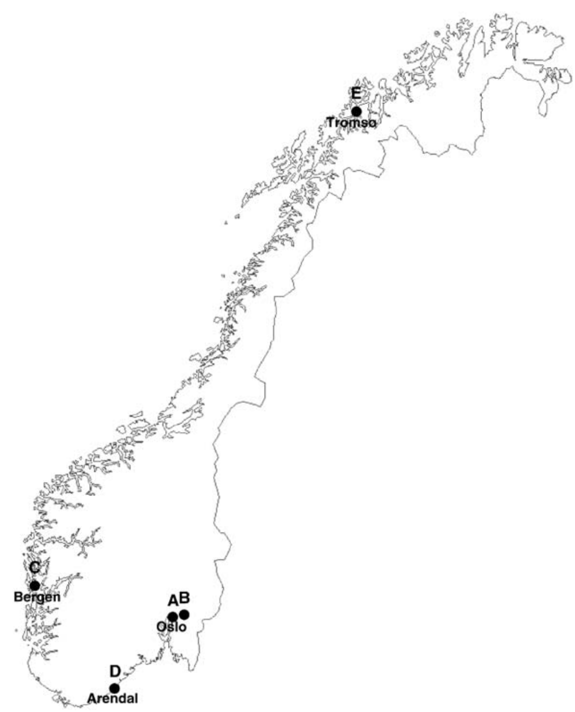

Fig. 1 – Localization of the five Norwegian WWTPs (A–E) included in the present study.

2.2. Sampling

Seven to 10 days time-proportional composite samples were collected from influent and effluent at the five WWTPs during spring and autumn 2002 using automatic sampling devices (BühlerMontec s1022, UK) equipped with teflon-coated rubber tubes and annealed 10 l glass vessels for storage. Sampling was repeated at two of the plants in 2004 (WWTP A and D). The storage vessels were kept at 4 °C during the sampling period. Samples were attempted collected during dry weather conditions only. However, as can be seen from Table 1, the total flow to the different plants in most periods exceeded the dry weather flow, indicating influence of storm water. Final samples for chemical analysis were preserved by sulphuric acid to below pH 2 (total organic carbon (TOC) and total phosphorous samples only) and stored at 4 °C in darkness, according to ISO 5667-3. Sample processing was started as soon as possible and usually within 1 week; however, samples for PBDE analysis were stored for 1–2 months before being processed.

2.3. Chemical analyses

All chemical analyses were performed at the laboratory of the Norwegian Institute for Water Research (NIVA) in Oslo. The laboratory is accredited by the Norwegian Accreditation as a testing laboratory, according to the requirements of NS-EN ISO/IEC 17025 for the determination of PAHs and PCBs. Analytical standards are also certified by the participation in