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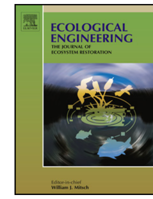

Distribution of metals in fauna, flora and sediments of wet detention ponds and natural shallow lakes

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ABSTRACT

Fauna, flora, and sediment were collected from 9 wet detention ponds receiving stormwater runoff and 11 small natural shallow lakes. The fauna and flora samples were sorted into species or groups of species and, together with sediments, analyzed for aluminum, copper, iron, zinc, arsenic, cadmium, chromium, nickel, lead, and phosphorus. There was a trend toward the studied wet detention ponds being more polluted by metals than the lakes. For the fauna this trend was statistically significant for all metals, while it for the plants was statistically significant for most of the metals. For the sediments, however, this observed trend was not statistically significant for any of the metals. Comparing the different metals accumulated in the sediments, the fauna, and the flora, no correlation between any of these could be detected. Neither fauna nor flora metal concentrations did correlate with sediment metal concentrations, and fauna metal concentrations did not correlate with flora metal concentrations. Comparing the diversity of species in the wet detention ponds and the shallow lakes, molluscs were more abundant in the wet detention ponds. For other fauna and flora, no clear difference between the diversity of species was observed.

1. Introduction

Stormwater runoff from urban areas, roads and highways contains pollutants that originate from the catchment surfaces. In most cases, the runoff conveys the pollutants to a receiving water body where they potentially cause harm (Grapentine et al., 2004). To mitigate environmental impacts on aquatic ecosystems, it is common practice to establish some treatment of the runoff prior to its discharge. One of the most common treatment options is wet detention pond (Hvitved-Jacobsen et al., 2010). A well-designed wet detention pond detains a large fraction of the particle-bound pollutants and stores it in the bottom sediments (Pontier et al., 2004). Typically, a wet detention pond has a permanent water body of 0.5–2 m depth and a surface area of some thousand square meters depending on the catchment area. A wet detention pond is typically constructed as an earthen basin with one or more inlets and one outlet. Its morphology is therefore rather similar to that of small natural shallow lakes.

Stormwater wet detention ponds are designed as treatment facilities, but as they in many ecological aspects resemble natural lakes, they quickly become invaded by aquatic flora and fauna. Wet detention ponds, hereby, act as aquatic ecosystems supporting the flora and fauna living there (Scher et al., 2004). However, wet detention ponds are designed to retain and accumulate pollutants in the bottom sediments and the flora and fauna therefore live in an environment of elevated pollutant content. Whether such ponds ultimately have positive overall effects on the biodiversity in a region is a topic of discussion, but some studies point toward this being the case (e.g. Le Viol et al., 2009; Brand and Snodgrass, 2010), while other studies point toward the fact that the ecological risks are not completely understood (Tixier et al., 2011).

One major group of pollutants retained in wet detention ponds is metals, which usually occur in elevated concentrations in the bottom sediments. The elevated metal concentrations may constitute a pool from where metals can migrate into aquatic plants and animals where they might accumulate in the tissue. For example Campbell (1994) reported elevated concentrations of certain heavy metals in fish from wet detention ponds compared to fish from rural shallow lakes. Stephansen et al. (2012) compared fauna from five wet detention ponds and five natural shallow lakes and found that metals were generally elevated in fauna from the ponds. For plants from anthropogenic lakes, Samecka-Cymerman and Kempers (2001) reported elevated concentrations of several heavy metals.

Comprehensive studies covering metals in aquatic flora, fauna, and sediments simultaneously are scarce. Reported studies have

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addressed flora, fauna, or sediments, or in a few cases flora and sediments or fauna and sediments simultaneously. It is the objective of this study to assess whether the metal concentrations of flora, fauna, and sediments in wet stormwater detention ponds are elevated compared to natural shallow lakes in order to get a better understanding of the bioaccumulation of metals in biota in such systems. Furthermore, we want to assess to what extent wet detention ponds can contribute to the biodiversity of a region.

2. Methodology

2.1. Field sample collection

Plants, water-dwelling fauna and sediments from nine wet detention ponds were sampled in the period from April to November 2010 (Table 1). The water phase was not sampled as pollutant concentrations in the water phase of stormwater ponds is known to undergo rapid short-term variability due to the intermittent nature of the pollutant load (e.g. Hvitved-Jacobsen et al., 2010). A grab sample would hence not be representative of the general level of pollutant concentration. Some ponds were located in industrial areas, some received highway runoff and some received stormwater runoff from housing areas. The ponds contain standing water all year round. The maximum water depths of the ponds were between 0.5 and 1.5 m. For comparison, 11 small and natural shallow lakes not receiving stormwater runoff were included in the investigation (Table 1). Of the lakes, 10 were rural and one was urban. The rural lakes were located in farmlands as well as woodlands.

Fauna samples were collected from the littoral zone and stored in 2.5 L plastic containers. Samples of all detected species were collected. Immediately after collection, the samples were placed on ice, transported to the laboratory, and within 24 h sorted into species. Prior to analysis, some species were lumped into related groups in order to ensure sufficient sample material for metal analysis. Pond sediments were sampled as intact cores by means of 5-cm diameter PVC pipes. The cores were taken near the middle of the ponds, mid-way between inlet and outlet. Lake sediments were sampled as intact cores at approximately 1/3 of the lake depth. Three cores were collected at each site. The uppermost 5 cm of the sediment profiles (the top layer) was immediately transferred to Rilsan bags for later analysis. Similar to the fauna samples, the sediment samples were kept on ice until they were taken to the laboratory for analysis. It was not possible to collect sediments at the site PC3 due to a raised water level caused by heavy rain prior to the sampling campaign. The flora samples were dug up, cleaned thoroughly in the field, and rinsed of the remaining soil using demineralized water upon arrival at the laboratory. LP4 had no plant growth, and metals in plants could therefore not be measured for this lake. When possible, the flora samples were divided into roots, shoots, stems, and leaves. Similar to sediments, the flora samples were stored in Rilsan bags.

2.2. Sample preparation

Samples were stored at −20 °C prior to freeze drying (ALPHA 1-2 LD plus, Martin Christ, Germany) at −55 °C at vacuum for 48 h. The dried fauna samples, except for clams, were crushed with a glass spoon. Due to a larger size of sampled individuals, clams were homogenized prior to freeze drying. Liquid nitrogen was added to the samples in a ceramic mortar, after which the samples were grinded with a pestle. The flora samples were cut into small pieces with titanium scissors. Subsamples of fauna, flora, and sediments (0.15–1.5 g) were after freeze drying and homogenization transferred to Teflon vessels. All samples were digested using microwave assisted acid digestion according to EPA 3051a (US EPA, 2007). 10 mL concentrated nitric acid (67–69% trace metal graded HNO_3, SCP Science, Canada) was added to the samples in the Teflon vessels and digested for 10 min in a microwave oven (Multiwave 3000, Anton Paar, Austria). Cooled digestates were diluted to volume with ultra pure water (NanoPure Diamond UV, Barnstead, Thermo Scientific), transferred to plastic flasks and allowed to settle before analysis of metals and phosphorus.

2.3. Analysis and quality assurance

Metal concentration and phosphorus was determined by Inductively Coupled Argon Plasma with Optical Emission Spectrometry detection (ICP-OES) (ICAP 6300 Duo View, Thermo Scientific). The elements were aluminum (Al), copper (Cu), iron (Fe), zinc (Zn), arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), and phosphorus (P). All elements were measured axially at

Table 1
The 20 sites included in the survey. Orange and green dots indicate stormwater retention ponds and natural shallow lakes, respectively. The area referred to is the water surface area. ADT: Average Daily Traffic. Sampling dates are all in 2010.

Pond classification	Site	Area (m^2)	Sample date	Description
	PR1 Silkeborg	3700	April 21	Had received aluminum salts to enhance treatment
Residential	PR2 Århus	6600	April 26	Had received iron salts to enhance treatment
	PR3 Lemming	1000	May 9	Located in a small rural village
	PC1 Sæby	600	May 4	Receives runoff from a highway truck center
Commercial	PC2 Odense	1800	May 6	Industrial area, known illicit discharges of pollutants
	PC3 Viborg	6000	August 30	Catchment; industry, parking lots and roads
	PH1 Vodskov	2500	July 13	ADT: 18,345 (Frederikshavn-highway)
Highway	PH2 Poulstrup	5100	July 15	ADT: 13,178 (Hirtshals-highway)
	PH3 Harlev	2700	July 27	ADT: 16,792 (Herning-highway)
Lakes				
City lake	LC1 Virklund	3400	August 4	Natural lake surrounded by a commercial catchment
	LA1 Rostrup	11,000	July 21	Surrounded by farmlands
Agriculture	LA2 Øster Doense	12,000	July 21	Surrounded by farmlands
	LA3 Dybvad	5500	July 9	Surrounded by farmlands, shielded by trenches
	LA4 Dorf	17,000	May 19	Old stemmed mill lake
	LP1 Sjørup	4300	May 16	Surrounded by plantation forest
Plantation	LP2 Auning	9500	May 21	Surrounded by plantation forest
	LP3 Gl Rye	5600	August 20	Surrounded by plantation forest and camping area
	LP4 Havris Hede	2500	August 25	Surrounded by plantation and heath
Forest	LF1 Poulstrup	11,000	May 13	Surrounded by forest harvest of macrophytes
	LF2 Hundsø	19,000	May 23	Surrounded by forest