Low nitrogen and phosphorus release from sediment deposited on a Danish restored floodplain

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Abstract – River floodplains and riparian areas are often considered efficient traps for sediment and sediment-associated nutrients such as nitrogen (N) and phosphorus (P). However, few studies have focused on the fate of sediment-bound N and P after deposition on floodplains. In this study, the leaching of N and P from sediment deposited on a Danish-restored floodplain was quantified by placing trapped sediment samples under a rainfall simulator and exposing them to *in situ* temperatures and precipitation for two months. The nitrate release was 2.72–1600 μg NO_3-N.g^{-1} DW which corresponded to 0.06–6.42% of the total nitrogen contained in the sediment. Total dissolved phosphorus (TDP) release was 0.44–3.17 μg P.g^{-1} DW, corresponding to 0.021–0.065% of the TP content of the sediment. Our results indicate that N and P release from floodplain sediment subjected to rainfall events is very low, which should be considered when applying floodplain restoration to mitigate the load of N and P to rivers.

Introduction

River floodplains are, in their natural state, an ecotone between aquatic and terrestrial ecosystems (Naiman and Decamps, 1997). Natural floodplains are uniquely positioned in the landscape, they exhibit important river-related hydrological and geomorphic processes and are recognized as valuable ecosystems with high biodiversity (Junk *et al.*, 1989; Naiman and Decamps, 1997; Ward *et al.*, 1999; Tockner *et al.*, 2000). Furthermore, floodplains are important zones for sediment deposition and exchange or transformation of nutrients in connection with the river (Naiman and Decamps, 1997; Tockner *et al.*, 1999; Pinay *et al.*, 2000, 2007).

However, human activities have greatly altered the valuable functionalities of the floodplains. For instance, works affecting the river such as regulation of river channels or construction of hydropower plants have disrupted the hydrological connection between rivers and floodplains and affected the frequency, extent and duration of flood events (Ward *et al.*, 1999). Also, agricultural activities have developed to such a degree that more than 90% of North American and European floodplains are cultivated (Tockner and Stanford, 2002). Consequently, degradation of the rivers and use of fertilizers combined with subsidence have led to leaching of nitrogen (N) and phosphorus (P) and the subsequent eutrophication of aquatic recipients (Carpenter *et al.*, 1998; Birgand *et al.*, 2007; Moss, 2008).

To combat eutrophication, restoration of rivers and riparian areas such as floodplains and river valleys has become an important way of reducing nutrient loads to aquatic systems (Mitsch and Jørgensen, 2003; Hoffmann and Baattrup-Pedersen, 2007; Moss and Monstadt, 2008) and improving the environmental state of valuable rivers and floodplain ecosystems or habitats. During flood events, a substantial amount of sediment may be deposited in floodplains and the N and P associated with this deposited sediment are therefore trapped in the floodplain, thus reducing the nutrient load to the river. Although deposition on floodplains is generally not considered a main process of N removal, deposition of particulate N in floodplains during inundation is also of importance (Olde Venterick *et al.*, 2006). Phosphorus is mainly transported in streams in particulate form and previous studies have shown that floodplains act as traps for sediment-bound P (Vought *et al.*, 1994; Olde Venterick *et al.*, 2006; Hoffmann *et al.*, 2009).

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Nevertheless, there are still some uncertainties regarding the efficiency of floodplains as a restoration measure (*e.g.*, Aldous *et al.*, 2007; Craig *et al.*, 2008) and especially about the fate of deposited nutrients after flood events (Noe and Hupp, 2009). Indeed, while several studies have documented N and P deposition in natural floodplains (Johnston, 1991; Brunet *et al.*, 1994; Walling *et al.*, 1999; Olde Venterick *et al.*, 2006, Kronvang *et al.*, 2007) or restored floodplains (Kronvang *et al.*, 1998, 2009), retention of the sediment-associated nutrients after their deposition has been overlooked. Therefore, quantification of N and P leaching from deposited sediment is of interest for estimating the efficiency of floodplain restoration as a permanent nutrient sink.

The main objective of this study was to investigate the N and P retention capacity of freshly deposited floodplain sediment. We examined the N and P leaching from sediment collected from a restored floodplain along River Odense in a laboratory set-up mimicking spring field conditions regarding temperature and rainfall over a 2-month period. We hypothesized that the exposure of fresh sediment to rainfall events may lead to leaching of N and P.

Materials and methods

Study site

The studied floodplain is situated 20 km south of the city of Odense (55°13'N, 10°15'W; Fig. 1) along the River Odense, a fifth-order stream with an average annual discharge of 6.5 $m^3.s^{-1}$ (Thodsen, 2007) and a slope of 0.127%. The River Odense discharges into Odense Fjord, which suffers from eutrophication (Petersen *et al.*, 2009). The catchment area of the River Odense encompasses *ca.* 1050 km^2 of lowland. The land is mainly used for agriculture, 68%, while urban areas occupy 16%, woodland 10% and lakes and wetlands 6% (Fyns Amt, 2003). The catchment soil type is mostly clay, 51%, and sandy loam, 49% (Fyns Amt, 2003). Annual precipitation is around 740 mm and annual mean temperature is 8.2 °C (Fyns Amt, 2003). During the first half of the 20th century, several stretches of the River Odense were straightened and channelized for agricultural purposes. But in autumn 2003, as part of a restoration project aiming at mitigating the nutrient load and improving the conditions for the river and the fjord, the floodplain was converted from arable land in crop rotation to a permanently grazed meadow. A total of 78.4 ha of riparian areas were restored by remeandering the river that enabled the groundwater level to rise and hence created wetter conditions in the surrounding areas (Kronvang *et al.*, 2009).
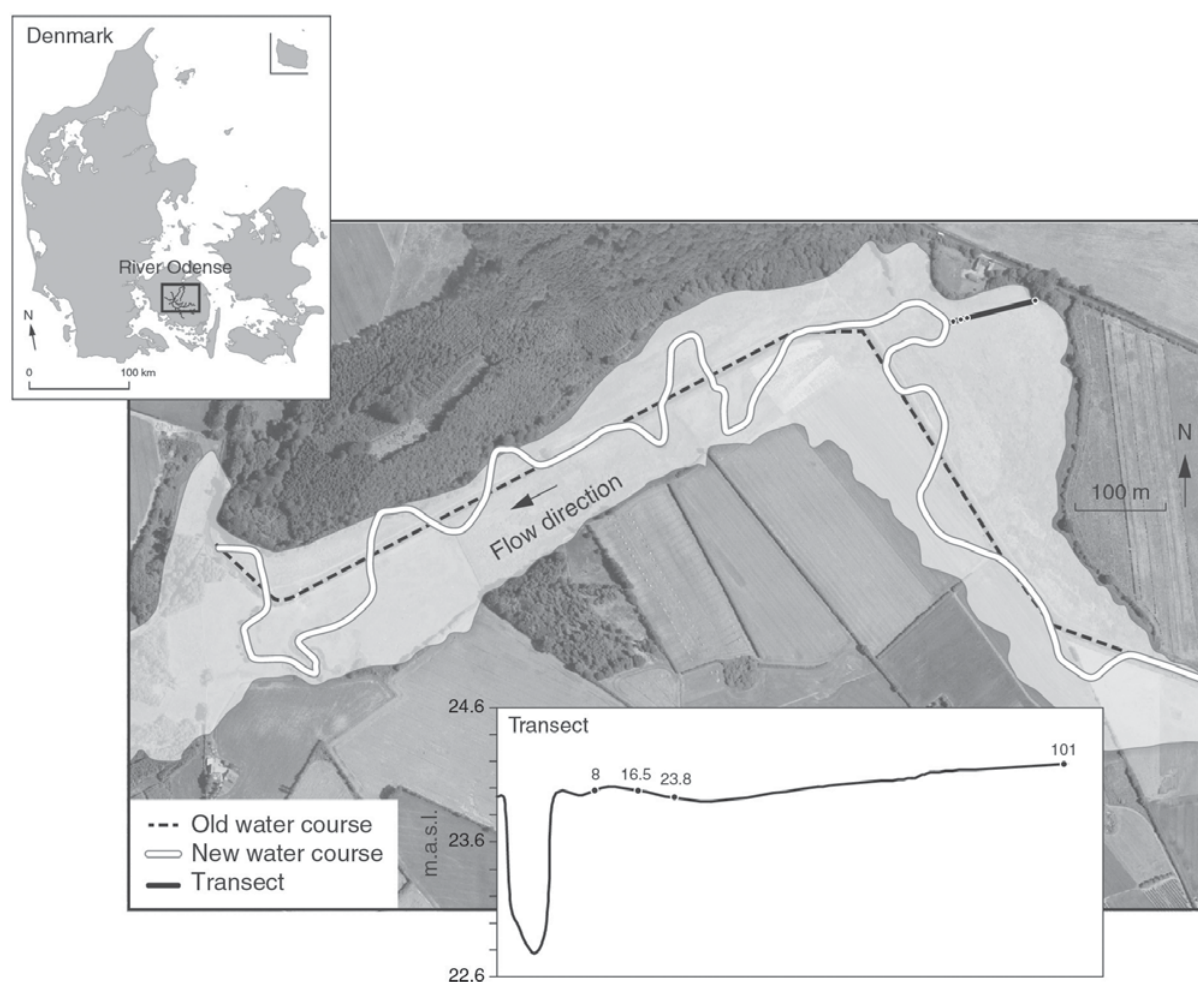
Field methods

Briefly, following Kronvang *et al.* (2009) sediment deposited on the floodplain during flood events was collected along a transect placed perpendicularly to the river channel (Fig. 1). A transect length extending from the river bank to the valley slope was chosen to cover the width of the floodplain. The sediment was trapped using duplicate large artificial grass mats (Astroturf® 30 × 30 cm, Textile Management Associates Inc., Dalton, GA, USA) that were placed at increasing distances along the transect (8, 16.5, 23.8 and 101 m; Fig. 1). Artificial grass mats were installed on the floodplain on October 24, 2007 and were harvested on March 26, 2008. Flooding events on the floodplain were recorded based on continuous water stage monitoring at a downstream river station (Nr. Broby, 55°15'N, 10°13'W). During the winter period of 2007–2008, the studied floodplain was flooded 68 days and the last flooding event ceased on March 25, 2008.

Laboratory procedures

After harvesting, the artificial mats with sediment were kept at 4 °C and in darkness until further processing. After 4–5 days, four artificial grass mats (one per sampling distance) were placed on a special-designed bottom tray lined with a 30 μm Nytal® mesh. Despite that only four mats were used in this experiment, we expected significant differences in sediment characteristics because of sediment textural sorting during deposition. The samples were not replicated in the incubation, but the size of the mats (30 × 30 cm) enabled us to obtain a large sample, especially when compared with smaller mats (15 × 15 cm) that are often used in sedimentation studies (*e.g.*, Kronvang *et al.*, 2007, 2009). The mats were subjected to simulated rainfall for two months in a climatic chamber under conditions that reproduced spring temperature (8 °C in the first month and 12 °C in the second month) and precipitation (43 mm in the first month and 47 mm in the second month) in Denmark. To mimic the alternation of rainy and dry periods, the monthly rainfall amount was divided into nine rain events. The amount of rainwater for each event was weighed out in a beaker and then pumped at a speed of 1.5 $mm.h^{-1}$. Thus, a rain event lasted between *ca.* 198 and 228 min. The precipitation was applied as two rain events on two consecutive days before allowing the sediment to air dry for five days. The constant rate of 1.5 $mm.h^{-1}$ simulated conditions of a light rain and is typical of Danish spring conditions (Vejen, 2005).

The rainfall simulator consisted of a 30 cm circular dosing head equipped with 180 needles. From a reservoir placed on a balance, artificial rainwater was applied to the artificial grass mats with deposited sediment using a peristaltic pump. The composition of the artificial rainwater was representative of Danish rainwater (Ellermann *et al.*, 2007; Ellermann, personal communication) and had the following nutrient concentrations: ammonium–N (NH_4) = 0.50 $mg.L^{-1}$, nitrate–N = 0.48 $mg.L^{-1}$, chloride = 5.76 $mg.L^{-1}$, potassium = 1.34 $mg.L^{-1}$, sodium = 2.67 $mg.L^{-1}$, calcium = 0.21 $mg.L^{-1}$, magnesium = 0.069 $mg.L^{-1}$ and sulfate = 0.273 $mg.L^{-1}$. The artificial rainwater that percolated through the sediment was caught in

Fig. 1. Map of the restored floodplain and profile of the transect showing the location of the artificial grass mats used to collect sediment deposited during flood event.

the bottom tray, which was connected to a sampling bottle placed underneath the tray. The collected water was sampled 5–6 h after each rainfall event and 24 h after the second rainfall event of every rainy period (*i.e.*, three samples per 2-day rain period). Exchange of nutrients between the sediment and the water phase was calculated as difference in nutrient concentration between the rainwater applied and the water collected after percolation through the sediment.

Water samples were immediately filtered through 0.45 μm filters (Cameo 25GAS filter). Ammonium–N and nitrate–nitrite–N (NO_3) in the water samples were analyzed according to the Danish/European standard (DS/EN ISO 13395, 1997; DS/EN ISO 11732, 2005) and measured spectrophotometrically at 660 and 520 nm, respectively, on Lachat FIA QC-8000. Phosphate (PO_4) was determined using the molybdenum blue method according to the Danish/European DS/EN ISO 6878 standard (2004) and measured spectrophotometrically at 880 nm on Lachat FIA QC-8000 (Lachat, Milwaukee, WI, USA). Total dissolved phosphorus (TDP) was determined as PO_4 following peroxydisulfate digestion in an autoclave (DS/EN ISO 6878, 2004). Dissolved organic phosphorus

(DOP) was determined as the difference between the concentration of TDP and PO_4 in the water sample.

Non-incubated sediment deposited on parallel grass mats was used to determine the sedimentation rate and characteristics of the sediment. The amount of sediment deposited was determined by drying 48 h at 60 °C and weighing the amount of dry sediment. Total phosphorus (TP) was determined as PO_4 after combustion in a muffle furnace at 550 °C and boiling of the ash with 0.1 M HCl (Andersen, 1976). Phosphorus in the sediment that adsorbed onto oxidized species of iron and manganese, often denoted as "the iron-bound P-fraction", was determined after extraction with bicarbonate–dithionite (BD reagent) (Psenner *et al.*, 1984; Paludan and Jensen, 1995). Iron (Fe) extracted by BD was analyzed by ICP (PerkinElmer Optima 2100, Waltham, MA, USA). This Fe is considered to represent ferric oxyhydroxides able to bind P (Psenner *et al.*, 1984; Jensen and Thamdrup, 1993). Organic matter (OM) was determined as loss on ignition after 3 h of combustion in a muffle furnace at 550 °C. Sediment samples were analyzed for total nitrogen (TN) and total organic carbon (C) using an automated C:N analyzer (Roboprep-G +) coupled to

Table 1. Deposition of sediment, TN and TP along a transect in the River Odense floodplain. Sediment content in TP, TN and OM. C:N is the carbon:nitrogen ratio in the sediment and Fe:PO_4 (by weight) is the iron:phosphate ratio in the iron-bound P fraction in the sediment. Different letters indicate significant differences ($P < 0.05$) between sediment located at different distances from the river bank. Results $\pm$ SE, number of replicates = 2.

Distance of sampling (m)	Sediment deposition (g DW.m^{-2})	TP deposition (g DW.m^{-2})	TN deposition (g DW.m^{-2})	TP (µg.g^{-1} DW)	TN (µg.g^{-1} DW)	OM (%)	C:N	Fe:PO_4
8	8969	19	41	2065 + 4[a]	4576 + 12[a]	21.2 + 3.8[a]	13.7 + 0.2[a]	11.2
16.5	4555	14	35	2997 + 13[a,b]	7709 + 30[b]	23.7 + 0.4[a]	11.9 + 0.4[b]	13.9
23.8	2391	8	25	3351 + 25[b]	10 456 + 10[c]	25.7 + 0.6[a]	10.1 + 0.0[c]	14.9
101	587	3	15	4830 + 2[c]	24 947 + 34[d]	64.0 + 0.1[b]	7.7 + 0.3[d]	39.6

a Europa Tracermass spectrometer (Europa Scientific, Crewe, Cheshire East, UK).

Statistical analysis

Sediment characteristics were analyzed by one way ANOVA and Tukey HSD *post-hoc* test was used for multiple comparisons. Linear regressions were used to fit the cumulated curve of nutrient exchange. When necessary the data were log transformed. The same transformation was applied to every curve of each data set to allow comparison of the slopes of the regressions following the procedure described in Zar (1999). Multiple comparisons among slopes were done using Tukey HSD *post-hoc* test. The significance level for all tests is $P < 0.05$.

Results

The total amount of sediment deposited during the winter period 2007–2008 decreased with increasing distance to the river. At a distance of 8 m the deposition was 8969 g DW.m^{-2} and at 101 m it was only 587 g DW.m^{-2} (Table 1). The TP content in the sediment increased gradually with distance to the river, ranging from 2065 to 4830 µg P.g^{-1} DW at 8 and 101 m, respectively (Table 1). Total N in the sediment increased gradually from 4576 µg.g^{-1} DW at a distance of 8 m to 24 947 µg.g^{-1} DW at 101 m (Table 1). Both TN and TP deposition reached maximum values 8 m from the channel and minimum values 101 m from the river (Table 1). The OM content increased slightly from 21 to 26% between 8 and 23.8 m from the channel, but then increased significantly to 64% in the sediment deposited at 101 m (Table 1). The C:N ratio decreased gradually from 13.7 to 7.7 at 8 and 101 m, respectively (Table 1). The Fe:PO_4 ratio (by weight) in the BD extracts rose gradually from 11.2 to 39.6 and from 8 to 101 m, indicating a higher P-binding capacity with increasing distance to the river (Table 1). One-way ANOVA revealed significant differences among the sediment samples as to the content of TP ($P < 0.01$), TN ($P < 0.001$), OM ($P < 0.001$) and C:N ($P < 0.001$). Results of multiple comparisons are presented in Table 1.

Each of the four mats received 90 mm of rainwater and this corresponded to an input of 86.5 mg N.m^{-2}

(*i.e.*, 51% as NO_3 and 49% as NH_4). Transformation of the N content in the rainwater to an input per gram of deposited sediment showed than N rainfall deposition ranged from 10 to 147 µg N.g^{-1} DW at 8 and 101 m, respectively.

A comparison of the NH_4 concentration in the rainwater and the water having percolated through the sediment revealed an uptake of NH_4 in the sediment (Fig. 2A). After 60 days of experiment, the uptake of NH_4 in the mat located at 8 m was 3.34 µg.g^{-1} DW, while the uptake of NH_4 in the mat located at 101 m was 47.4 µg.g^{-1} DW (Table 2).

Nitrate was leached from the sediment on the mats which was evidenced by the fact that the NO_3 concentration in percolating water was higher than NO_3 concentration in rainwater (Fig. 2B). The NO_3-release from the sediment ranged from 2.72 to 1600 µg.g^{-1} DW at 8 and 101 m, respectively (Table 2). The total release of dissolved inorganic N species (only NO_3 in this case) after 60 days of experiment varied between 0.06 and 6.42% of TN content in the sediment.
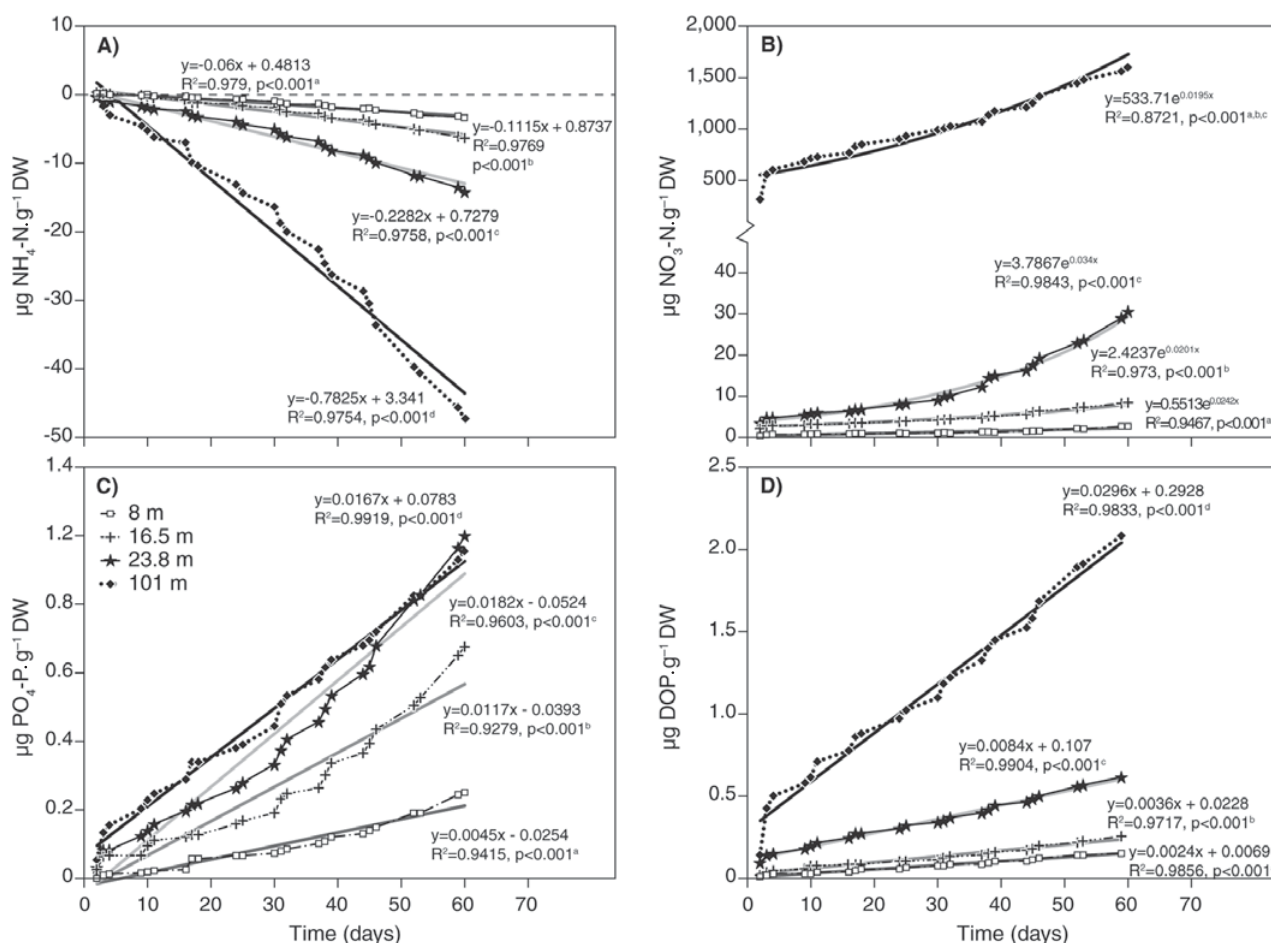
During the 60 days of the experiment, a release of PO_4 from the sediment to the water phase occurred (Fig. 2C). The amount of PO_4 released from the sediment after 60 days varied between 0.29 and 1.17 µg P.g^{-1} DW at a distance of 8 and 23.8 m from the river channel, respectively (Table 1).

Release of DOP from the sediment increased with increasing distance to the river channel (Fig. 2D). At the end of the experiment, the amount of DOP released to the water ranged between 0.16 and 2.03 µg P.g^{-1} DW at 8 and 101 m, respectively (Table 1). The release of TDP (*i.e.*, PO_4 + DOP) during the experiment ranged between 0.021 and 0.065% of the TP content in the sediment deposited at a distance of 8 and 101 m from the river channel, respectively.

The comparison of NH_4 uptake rates showed significant differences ($F_{3,88} = 1059$, $P < 0.001$) and the highest uptake rate was found in the sediment deposited at 101 m (Fig. 2A). Nitrate release rates demonstrated significant differences ($F_{3,88} = 46$; $P < 0.001$), but the release rate in the sediment found at 101 m did not differ significantly from those in the other sediments (Fig. 2B). Phosphate release rates were significantly different ($F_{3,88} = 394$, $P < 0.001$) and the highest rate was found at 23.8 m (Fig. 2C). DOP release rates exhibited significant

Table 2. Exchange of ammonium (NH_4), nitrate (NO_3), phosphate (PO_4) and DOP between the sediment and the water phase after a 2-months simulation period of spring temperatures and rainfall. Negative values indicate uptake by the sediment.

Distance of sampling (m)	NH_4 (μg N.g^{-1} DW)	NO_3 (μg N.g^{-1} DW)	PO_4 (μg P.g^{-1} DW)	DOP (μg P.g^{-1} DW)
8	− 3.34	2.72	0.29	0.16
16.5	− 6.38	8.45	0.79	0.25
23.8	− 14.1	30.6	1.17	0.62
101	− 47.4	1600	1.12	2.03

Fig. 2. Cumulated concentration of (A) ammonium (NH_4), (B) nitrite + nitrate (NO_3), (C) phosphate (PO_4) and (D) DOP in the water collected after percolation through the sediment deposited in the River Odense floodplain at different sampling distances. Different letters indicate significant differences ($P < 0.05$) between the slopes of the curves.

differences ($F_{3,84} = 758$, $P < 0.001$) and increased with increasing distance to the channel (Fig. 2D).

Discussion

Several studies have demonstrated the importance of floodplains as a trap for sediment and sediment-associated nutrients (Walling *et al.*, 1999; Olde Venterick *et al.*, 2006; Kronvang *et al.*, 2007; Noe and Hupp, 2009). In the present study, the sedimentation rates found for the restored floodplain (Table 1) are comparable with the values measured in 21 floodplains in the UK (400–12 200 g.m^{-2}.yr^{-1}; Walling *et al.*, 1999) and also with sedimentation rates at 17 sites located along rivers in the Chesapeake watershed in the USA (303–4600 g.m^{-2}.yr^{-1}; Noe and Hupp, 2009). A study conducted by Kronvang *et al.* (2007) in four Danish floodplains revealed deposition rates between 3000 and 6570 g.m^{-2}.yr^{-1}. However, a much higher deposition rate of 23 000 g.m^{-2}.yr^{-1} was found in a floodplain located along the River Danube in Austria (Tockner *et al.*, 1999).

Total N deposition measured in this study (Table 1) is of the same order of magnitude as the rates found in five Dutch floodplains (4.2–56.8 g N DW.m^{-2}.yr^{-1}; Olde Venterick *et al.*, 2006) and in North American coastal

floodplains (2.2–12 g N DW.m^{-2}.yr^{-1}; Noe and Hupp, 2009). Total P deposition (Table 1) was higher compared to values of 0.2–3.5 g P DW.m^{-2}.yr^{-1} found by Noe and Hupp (2009) and in four Danish floodplains (1.2–7.3 g P DW.m^{-2}.yr^{-1}; Kronvang et al., 2007).

The sediment released NO_3, but took up NH_4. However, the total inorganic N release from the sediment did not exceed 6.42% of the TN content in the sediment. A possible explanation for this might be that the NH_4 originating from the rainwater was adsorbed on minerals, taken up by bacteria or transformed to NO_3 in the sediment. According to Drury and Beauchamp (1991) and Trehan (1996), adsorption of NH_4 on clay minerals is prompt (< 30 min), but generally accounts for less than 10% of the NH_4 applied to soil. Brookes et al. (1985) found that 10–34% of NH_4 in soils is immobilized by micro-organisms, and this indicates that micro-organisms may have contributed to the uptake of NH_4. In our study, some of these micro-organisms may have been nitrifiers that transform NH_4 to NO_3. Therefore, it seems likely that part of NO_3 leached by the sediment originated from rainwater NH_4. Assuming that the whole NH_4 uptake is nitrified to NO_3 and subsequently released, it signifies that, since the NO_3 release from the sediment deposited from 16.5 to 101 m is larger than the NH_4 uptake, part of the NO_3 does not come from the rainwater but originates from the mineralization of OM.

The sediment showed significant differences regarding NH_4 uptake rates, which increased with increasing distance to the river. Furthermore, the rates of NO_3 release also revealed marked differences even though the release rate of the sediment collected at 101 m did not differ significantly from those recorded in the other sediments. These differences might be explained by contrasting sediment characteristics (i.e., TN and OM content and C:N ratio) due to textural sorting during deposition on the floodplain. During overbank flooding, coarse particles are generally deposited closer to the river banks, while fine particles richer in nutrients may deposit further away (Kronvang et al., 2007). Additionally, bacterial activity is favored by low C:N ratios (Reddy and Delaune, 2008) and this may explain the higher NH_4 uptake (by increased microbial uptake or nitrification) with increasing distance to the river. Increasing release of NO_3 with increasing distance to the river might be explained both by higher mineralization and higher nitrification in relation with higher TN and OM contents in the sediment as well as by higher bacterial activity due to the lower C:N content.

The release of PO_4 and DOP was very low and did not account for more than 0.065% of the total P content in the sediment. The Fe:PO_4 ratio in the iron-bound P fraction, which is often used as an indicator of the potential PO_4 release (Jensen and Thamdrup, 1993), was relatively low (i.e., < 15, by weight) in the sediment collected between 8 and 23.8 m, but high (40) in the sediment collected at 101 m. Jensen et al. (1992) found that an Fe:P ratio of at least 15 was needed to prevent PO_4 release from aerobic freshwater sediment. Surprisingly, despite that the deposits had a high P content and some of them low Fe:PO_4 the

release of PO_4 was negligible. This might be due to the fact that freshly deposited sediment might contain a high amount of amorphous iron oxyhydroxides which can offer more binding sites for PO_4 than crystallized iron oxyhydroxides (Loeb et al., 2008) even at low Fe:PO_4.

DOP release rates differed significantly among the sediments, with increasing rates in the sediment deposited further away from the river. An explanation for this may be increasing contents of TP and OM in the sediment (i.e., a larger P pool) with increasing distance to the river. Also, increasing sediment mineralization rates with increasing distance to the river may have increased P mobilization and release, and this is consistent with the release rates of NO_3.

Under natural conditions, part of the N and P leached from the sediment may be used for plant uptake. In fact, the amount of P released during the experiment may supply the amount of P needed for plant growth in April and May. In our study, the highest release of TP amounted to 0.55 g TP.m^{-2}, and in Denmark meadow plants need between 0.2 and 0.3 g TP.m^{-2} to cover aboveground production in April and May (Hoffmann et al., 2006). The highest N release in the experiment was 0.94 g N.m^{-2}, and plant N uptake by Danish meadow plants varies from 2.3 to 4.3 g N.m^{-2} (Hoffmann et al., 2006).

The rainfall simulated was of light intensity and it might be assumed that under natural conditions intense rainfall events may contribute to nutrient leaching because of physical disruption of the sediment particles. Also, the soil moisture content in the incubated sediment differed from that under field conditions. Furthermore, this experiment did not test the effect of intra-day variation in temperature, which may have affected biological processes such as mineralization (Stanford et al., 1973) or nitrification (Frederick, 1956).

Despite that our results show positive N and P retention values in floodplain sediment, more investigations are needed to follow the nutrient retention over longer time periods, especially when the sediment is re-flooded and becomes anaerobic, which potentially may lead to substantial P release of Fe bound P. As in the case of nitrogen, release of organic N was not measured in this study but might have contributed significantly to the N release. Furthermore, the low N release might also be explained by the fact that the sediment was immersed in the river water before its deposition, enabling release of soluble N. Even though this experiment was performed under aerobic conditions, NO_3 removal by denitrification may have occurred at some small anaerobic spots in the sediment, thereby lowering the leaching of NO_3.

Overall, our findings have important implications for estimating the efficiency of river and floodplain restoration projects to mitigate the nutrient load. Our study demonstrated that a substantial amount of sediment and associated N and P may be deposited on restored floodplains. Furthermore, despite a high nutrient content, the release of N and P from sediment exposed to spring rainfall amounts and spring temperatures was negligible, and part of the release might also be used to sustain plant growth.

Consequently, our results support the idea that floodplain and river restoration is a relevant tool for mitigating the nutrient load to aquatic freshwater ecosystems. This is of importance in countries where there is a need to preserve or improve water resources, especially in Europe where the implementation of the Water Framework Directive (European Parliament and of the Council, 2000) requires that all water bodies have achieved good environmental status by 2015. Our results confirm the relevance of applying restoration measures in Denmark where an objective of restoring 16 000 ha of wetland and riparian areas has been established (Hoffmann and Baattrup-Pedersen, 2007).

Conclusion

The purpose of our study was to test nutrient retention in fresh sediment collected in a restored floodplain and placed in an experimental setup simulating spring rainfall and temperatures. Our findings show that restored floodplains act as efficient traps for sediment and sediment-associated nutrients and that the release of P and inorganic N is very low despite a high content of nutrients in the sediment. The results of our study support the relevance of applying restoration of river floodplains to mitigate the nutrient load to aquatic recipients such as lake and fjords. Further investigations are needed to monitor the retention over a longer time period, in particular, when the sediment is rewetted.

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