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Contribution of cation exchange property of overflow wetland peat to removal of NH_4^+ discharged from some Finnish peat mines

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Abstract—The importance of adsorption on peat for decreasing NH_4^+ was estimated in four overland flow areas (OFA) in northern Finland, where peat mining water is purified by conducting it across a natural mire of a given size. The effective cation exchange capacity (ECEC) values of peat in the OFAs ranged from 21.4 to 92.7 meq per 100g, being generally highest in the surface 0–15 cm. It was estimated that about 4.6–5.8% of the peat cation exchange sites could be occupied by NH_4^+, corresponding to a NH_4^+ retention capacity of about 0.18 to 0.77 g kg^{-1} dry peat. Assuming that the retention was attributable to the 0–15 cm surface peat layer alone, the calculated NH_4^+ retention potential of OFA peat should have lasted under 6 months with the loadings imposed on the OFAs and the decreases in NH_4^+ amounts in peat mining water considered here. The actual duration of peat capacity to retain NH_4^+ in the OFAs has, however, already been shown in this research to be longer, and apparently will be so also in future, probably as a result of two processes: nitrification and subsequent N loss through denitrification, and biological assimilation. Hence, cation exchange capacity of OFA was an important property that contributed to surface water protection against eutrophication by N.

INTRODUCTION

Peat mining causes suspended matter and nutrients to leach into the lakes and rivers below the site. Transport rates of inorganic nitrogen can be especially pronounced (Heikkinen, 1990). Research has shown that N loss is the limiting factor for primary production in the Bothnian Bay, the northernmost part of the Baltic Sea (Alasaarela, 1980), and probably also in the majority of the Finnish rivers (Heikkinen, 1990; Pietiläinen and Kauppi, 1993), the peaty drainage basins of which contain most of the peat mining areas. Since high N inputs will cause eutrophication, it is important to develop water pollution control methods for reducing the N loading imposed on these watercourses.

An effective way of reducing the loading from peat mining areas involves the overland flow technique. This method corresponds to that in household waste water purification, which has been employed since the 1950s. The technique involves conducting the water from a peat mining area across a natural mire of a given size. It removes not only suspended matter, like the sedimentation basins generally used in the purification of peat mining water, but it is also effective in removing soluble inorganic elements and some soluble organics (Ihme *et al.*, 1991; Ihme, 1994). The NH_4^+ decreases achieved in an overland flow area (OFA) adjacent to the peat mining site of Kompsasuo, which is situated in the minerotrophic peatland area in northern Finland, averaged 62–90% in 1987–1991, and the decrease in total inorganic N and total N was 56–70 and 34–71%, respectively (Ihme *et al.*, 1991; Ihme, 1994). The N decrease reported in household waste water with this method has also been high, generally over 80% for total N and NH_4^+ (Surakka and Kämppi, 1971; Tilton and Kadlec, 1979; Kadlec and Hammer, 1988).

There are still unanswered questions regarding the processes involved in decreasing NH_4^+ loading and the long-term capacities of peatland ecosystems to remove nutrients from waste water. Denitrification is thought to be the major mechanism for NO_3^- removal from waste water spread over wetlands (Lance, 1972; Bowden, 1987; Nichols, 1983; Adamus and Stockwell, 1983). Although N is also retained by the peat microbes and plants, it is likely that these pools serve only as short-term sinks for N (Broadbent and Nakashima, 1970; Spangler *et al.*, 1976; Nichols, 1983). Ammonium ion adsorption on peat by means of charged organic colloids is similarly assumed to be an important N removal process in northern peatlands (Bastian and Benforado, 1988).

The capacity of peat to retain NH_4^+ is, however, limited and its maximum level can be estimated using values for cation exchange capacity (CEC), a measure of the quantity of readily exchangeable cations neutralizing negative charges in the soil (Lance, 1972). Since CEC varies with pH, methods involving the use of buffered solutions with high pH values and high electrolytic concentrations give values that overestimate the CEC of acid soils. In order to estimate the actual NH_4^+ retention potential of peat in CEC at the pH values prevailing in the OFAs, it is necessary to measure the effective CEC (ECEC), i.e. the CEC determined by successively treating a soil sample with nonbuffered salt solutions adjusted to soil pH.

The aim of the present research was to estimate the importance of CEC property of peat in NH_4^+ removal from peat mining water in OFAs, and to predict the duration of NH_4^+ retention.

SITE DESCRIPTIONS

The sites are situated in the minerotrophic mires of Kompsasuo and Puutiosuo in northern Finland (Fig. 1). These mires are surrounded by coniferous forests of the mid-boreal type. The northern OFA at Kompsasuo is a pine mire with a mire margin effect in its lower part, and covers an area of *ca* 2.4 ha. The OFA constitutes 4.8% of the catchment area. The vegetation typical of this area includes *Salix sp.*, *Vaccinium sp.*, *Empetrum nigrum*, *Ledum palustre*, *Menyanthes trifoliata* and *Carex sp.* The peat types comprise *Menyanthes–Carex–Sphagnum* peat, occurring in the surface layer, and *Sphagnum–Carex* peat, found deeper down. The size of the southern OFA at Kompsasuo is *ca* 1.9 ha, constituting 1.5% of the catchment area. The prevailing peat types are *Carex–Sphagnum* peat in the surface layer and *Sphagnum* and *Carex* peat in the deeper horizons. The OFAs at Puutiosuo are oligotrophic sedge fens. The northern area covers *ca* 10 ha and the southern area *ca* 1.4 ha, constituting 8.5% and 1.4% of the catchment areas, respectively. *Carex sp.* and *Eriophorum sp.* cover about 20% of the northern area and about 58% of the southern area. Other randomly occurring plants in the areas include *Vaccinium sp.*, *Empetrum nigrum*, *Andromeda polifolia* and *Menyanthes trifoliata*. The prevailing peat types are *Polytrichum–Sphagnum* peat in the northern area and *Eriophorum–Sphagnum* peat in the southern one. More detailed descriptions of the OFAs are given in Ihme *et al.* (1991) for Kompsasuo and in Ihme (1994) for Puutiosuo.

The Kompsasuo mire was prepared for mining in 1986–1989 and that of Puutiosuo in 1987–1991. Sod peat was occasionally lifted from Kompsasuo in summer 1989 and 1991, but Puutiosuo was still at the preparation stage when this work was carried out. The water draining from the northern parts of these peat mining areas flows through sedimentation basins and OFAs and that from the southern parts only through OFAs (Ihme *et al.*, 1991; Ihme, 1994). Water flows from the peat mining area and the possible sedimentation basin via the outlet ditch to the distribution ditch located in the upper part of the OFA (Fig. 1). The water which has flowed across the area is conducted to the outlet ditch below the area by means of the collection ditches. At the start of this research the OFAs at Kompsasuo, the northern part of Puutiosuo and the southern part had been in use for 6, 3 and 5 y, respectively.

The suitability of the overland flow method for purifying peat mining water was examined by full-scale field methods at Kompsasuo and in two other peat mining areas in northern Finland in 1987–1989 (Ihme *et al.*, 1991), and the findings were used to draw up planning, construction and maintenance instructions. The research was then continued in 1990–1993 to identify the main factors contributing to the retention of suspended solids, organic matter, Fe and nutrients in the OFAs, and to estimate the service life of these water pollution control devices (Heikkinen *et al.*, 1994; Heikkinen and Ihme, 1994; Ihme, 1994).

MATERIALS AND METHODS

Peat samples were taken from the middle part of the OFA at the northern part of Kompsasuo and from peatland about 50 m beyond this area (reference area, RA) at the beginning of November 1991, and from the middle parts of all the OFAs and from the RAs in September 1992. Samples were taken from depths of 0–5, 5–15 and 15–25 cm at each site.

The effective CEC of peat was determined by a modification of the method proposed by Gillman *et al.* (1983) and Hendershot and Duquette (1986). Field moist peat samples (about 15 g, 2 replicates) were weighed in acid-washed centrifuge tubes, 40 ml of 0.1 M $BaCl_2$ solution (pH 5.3) was added, and the samples were agitated for 30 min by Edmund Bühler KL2 shaker. The suspension was centrifuged, and the supernatant was filtered through Whatman GF/C and Schleicher & Schuell 583^3 (Blue ribbon) filters, after which another 40 ml $BaCl_2$ solution was added to the tubes. The samples were shaken manually quite vigorously for about 1 min, centrifuged and filtered as described earlier. Two more extractions were carried out following the same procedures.

Sodium, K, Mg, Ca, Al and Fe concentrations in the filtrates were analysed using a Perkin–Elmer Atomic Absorption Analyser, and the H^+ concentration was computed from pH data determined in the filtrates on a Radiometer

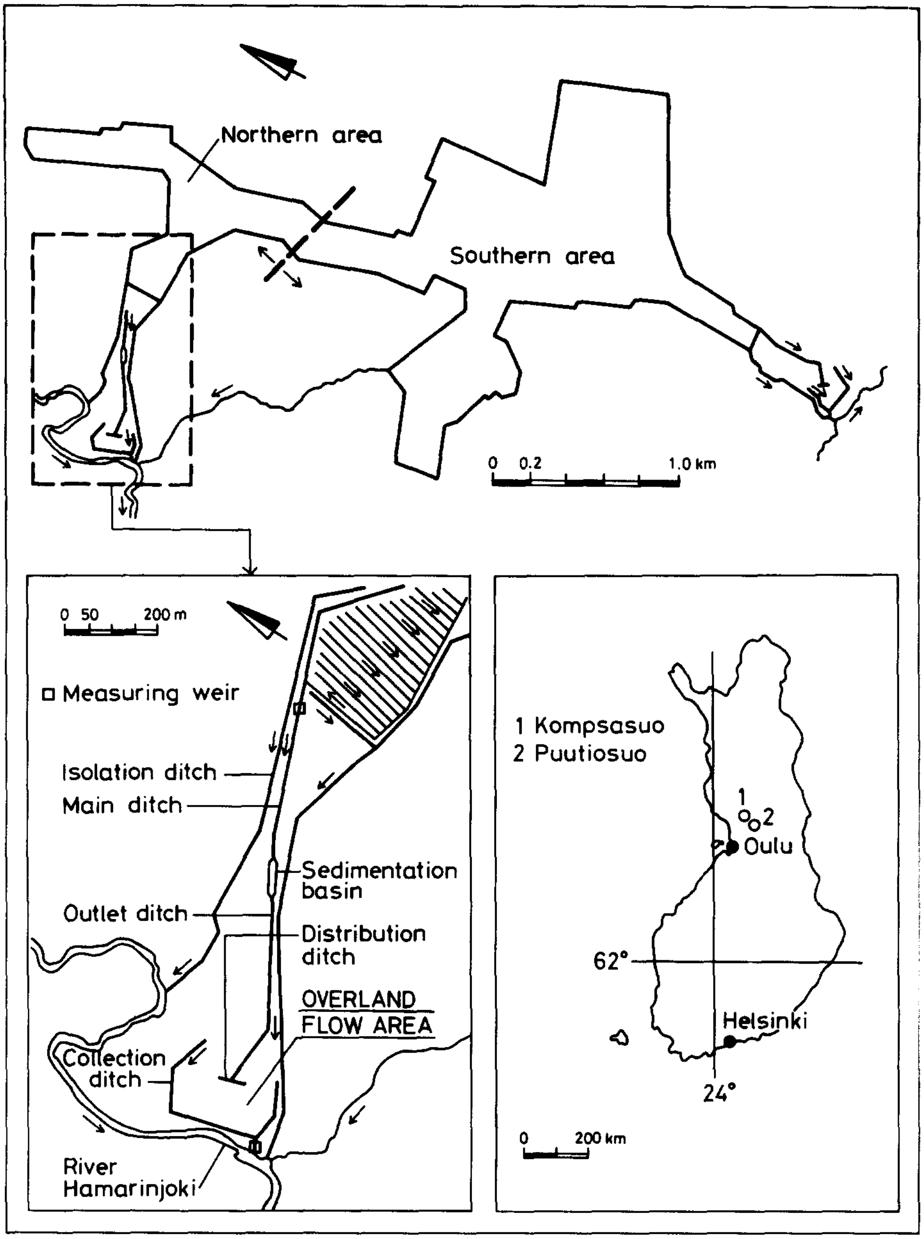

Fig. 1. Location of mires, and the Kompsasuo peat mining area containing the water pollution control devices.

PHM 82 meter. The NH_4–N concentrations were analysed spectrophotometrically by the salisylate method (International Organization for Standardization, 1984). The effective CEC was estimated from the sum of the H^+, Al^{3+}, Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+} and NH_4^+ concentrations meq per 100 g dry peat.

The ability of the peat to adsorb NH_4^+ was estimated using the effective CEC values. The peat cannot be saturated with NH_4^+, because other ions in the water, particularly Ca^{2+} and Mg^{2+}, compete for the exchange sites. The percentage of the CEC that can be occupied by NH_4^+ (exchangeable ammonium percentage, EAP) was calculated, according to Lance (1972), as:

$$\mathrm{AAR} = \frac{[\mathrm{NH_4^+}]}{(1/2[\mathrm{Ca^{2+}}] + 1/2[\mathrm{Mg^{2+}}])^{1/2}} \qquad (1)$$

$$\mathrm{EAP} = \frac{100(0.0360 + 0.1051\ \mathrm{AAR})}{1 + (0.0360 + 0.1051\ \mathrm{AAR})} \qquad (2)$$

where: AAR = NH_4^+ ion adsorption ratio used to characterise the relative ammonium status of water, concentrations are expressed in meq L^{-1}

The dry weight of each peat sample was measured at room temperature, and the degree of humification estimated on the von Post scale (von Post, 1922). The density of the peat taken from the northern OFA at Kompsasuo was measured in October 1991 and September 1992, and that of the other OFAs in September 1992. These measurements were then used to calculate approximate total amounts of dry peat contained in the OFAs. The NH_4^+ retention potential of the 0–25 cm surface peat layer was estimated on the basis of the NH_4^+ retention capacity of peat determined and the approximate total amounts of dry peat contained in the OFAs, taking into account the rates of utilization. The utilization rates of the OFAs, i.e. the distribution of water, were estimated weekly by eye as a percent of the total area.

The hydraulic loadings imposed on the OFAs were continuously monitored by triangular Thompson's measuring weirs equipped with graphic water level recorders. Water samples were taken weekly above and below the OFAs in 1987–1992 at Kompsasuo and in 1990–1992 at Puutiosuo and analysed for total N, NH_4-N and NO_3-N (National Board of Waters, 1981). This monitoring has been continued also in 1993. The decreases in N amounts achieved were calculated as a difference between the amounts in the inflow and outflow and reported in detail in Ihme *et al.* (1991) and Ihme (1994). Calcium and Mg concentrations in the water flowing into the OFA were measured at weekly intervals in 1992 in the northern part of Kompsasuo. In the other OFAs studied Ca and Mg were measured in 1993.

RESULTS

The ECEC values ranged from 21.4 to 92.7 meq per 100 g in the OFAs and from 18.2 to 74.7 meq per 100 g in the RAs (Tables 1 and 2), being generally

Table 1. Effective cation exchange capacity (ECEC) of peat, extent of the exchange sites occupied by various cations and pH and the degree of humification (H°) of peat at Kompsasuo peatland

Sampling place/ layer (cm)		ECEC (meq per 100g)	Exchange sites occupied (%)									
			Ca^{2+}	Mg^{2+}	Na^+	K^+	Fe^{2+}	NH_4^+	Al^{3+}	H^+	pH	H°
Northern part												
OFA 1991	0–5	86.5	80.00	16.00	0.48	0.20	0.16	0.14	0.10	3.00	3.67	3
	5–15	90.4	78.00	18.50	0.68	0.52	0.15	0.15	0.04	2.00	3.77	2
	15–25	77.6	80.50	16.00	0.74	0.05	0.11	0.10	0.04	3.00	3.54	4
RA 1991	0–5	37.4	35.59	18.50	1.00	0.68	0.37	0.20	0.40	44.50	2.94	1
	5–15	33.3	72.50	15.50	2.00	0.37	0.44	0.67	0.25	8.50	3.46	4
	15–25	26.4	80.00	11.00	1.00	0.17	0.33	0.75	0.21	6.00	3.65	4
OFA 1992	0–5	91.0	75.50	19.50	1.00	0.30	0.63	1.00	0.05	3.00	3.77	2
	5–15	92.7	78.00	16.50	1.00	0.19	0.22	0.46	0.08	3.50	3.67	2
	15–25	66.2	79.50	15.50	1.00	0.13	0.28	0.34	0.05	3.50	3.61	4
RA 1992	0–5	42.0	50.00	32.50	4.50	1.00	1.00	1.00	0.19	10.00	3.70	1
	5–15	58.6	60.00	16.50	2.00	0.32	1.50	0.38	0.13	19.50	3.20	2
	15–25	33.1	69.50	11.00	2.50	0.13	8.50	0.31	0.07	8.00	3.47	4
Southern part												
OFA 1992	0–5	57.6	64.00	19.00	1.00	0.34	8.50	1.00	0.09	6.00	3.57	4
	5–15	58.2	72.50	19.00	1.00	0.27	0.27	1.00	0.06	5.00	3.50	4
	15–25	55.2	74.50	18.50	1.00	0.37	0.24	1.00	0.03	4.50	3.51	4
RA 1992	0–5	74.7	42.00	11.00	1.00	0.37	41.50	0.20	0.01	4.50	3.64	4
	5–15	33.6	66.00	18.50	1.50	0.39	1.00	0.38	0.05	12.00	3.41	3
	15–25	34.0	67.50	14.50	1.50	0.35	6.00	0.39	0.02	10.00	3.49	3

OFA = overland flow area; RA = reference area.

Table 2. Effective cation exchange capacity (ECEC) of peat, extent of the exchange sites occupied by various cations and pH and degree of humification (H°) of peat at Puutiosuo peatland

Sampling place/ layer (cm)		ECEC (meq per 100g)	Exchange sites occupied (%)									
			Ca^{2+}	Mg^{2+}	Na^+	K^+	Fe^{2+}	NH_4^+	Al^{3+}	H^+	pH	H°
Northern part												
OFA 1992	0–5	67.7	60.50	29.00	1.00	0.38	1.00	1.00	0.02	6.50	3.64	1
	5–15	48.4	44.00	30.00	2.00	0.37	2.00	1.00	0.24	21.00	3.23	2
	15–25	21.4	36.50	17.50	4.50	1.00	1.50	2.50	0.41	36.50	3.11	4
RA 1992	0–5	39.8	24.00	22.00	3.00	0.75	2.00	1.00	1.00	46.50	3.03	1
	5–15	40.2	25.00	17.00	2.00	0.44	1.50	1.00	10.50	43.50	3.02	1
	15–25	40.1	21.50	11.00	2.50	1.00	1.00	2.00	24.50	36.00	3.11	2
Southern part												
OFA 1992	0–5	73.5	67.50	24.50	1.00	0.28	0.30	2.00	0.04	4.00	3.69	5
	5–15	64.7	40.50	49.00	1.50	0.29	1.20	2.00	0.04	5.50	3.78	2
	15–25	35.2	57.00	25.00	2.50	0.42	1.50	2.00	0.19	10.50	3.39	3
RA 1992	0–5	27.6	43.00	17.00	2.00	1.00	2.00	1.00	0.43	34.00	2.98	6
	5–15	19.5	51.00	18.00	2.00	0.42	1.00	1.00	0.38	26.00	3.14	4
	15–25	18.2	56.00	18.00	2.00	0.36	1.00	2.00	0.47	20.00	3.26	6

OFA = overland flow area; RA = reference area.

Table 3. The NH_4^+, Ca^{2+} and Mg^{2+} concentrations in the incoming water, percentages of the peat exchange sites that can be occupied by NH_4^+ (NH_4^+ % ES), average utilization rates (UR), total dry weight of the peat and NH_4^+ retention capacity of the peat in the overland flow areas

OFA/layer (cm)	Concentration			NH_4^+ % ES	UR (%)	Dry weight of peat (t)	NH_4^+ (g kg^{-1})
	NH_4^+	Ca^{2+}	Mg^{2+}				
Kompsasuo northern	1.0	6.3	1.8	4.6	64		
0–5						49	0.77
5–15						140	0.72
15–25						204	0.55
Kompsasuo southern	0.9	4.7	1.1	4.7	75		
0–5						70	0.49
5–15						185	0.49
15–25						166	0.47
Puutiosuo northern	0.8	3.7	1.4	4.6	47		
0–5						186	0.56
5–15						245	0.40
15–25						440	0.18
Puutiosuo southern	1.3	2.0	1.0	5.8	73		
0–5						50	0.77
5–15						57	0.67
15–25						116	0.37

highest in the surface 0–15 cm. The values tended to decrease with depth. The pH of the 0–15 cm surface peat measured from the $BaCl_2$ solution was higher in the OFAs than in the RAs, especially at the study area of Puutiosuo. The degrees of peat humification ranged from 1–6 and generally increased with depth in the northern study areas. The highest von Post values were often measured in the surface 0–5 cm layers in the southern areas.

Calcium ions and Mg^{2+} occupied most of the exchange sites measured in the OFAs and RAs at Kompsasuo (Table 1). In contrast, H^+ ions represented a higher proportion of the CEC in the RA of the northern part than in the OFA. A similar trend of events was recorded in the southern part, with the 0–5 cm peat layer being the exception. Calcium ions and Mg^{2+} were often the most important cations occupying the exchange sites measured in the OFAs and RAs of Puutiosuo also (Table 2), but the role of H^+ ions was generally much more marked than in the Kompsasuo areas. The amount of exchange sites occupied by H^+ increased in the deeper peat layers, and was lower in the 0–15 cm peat layer in the OFAs than in the RAs. Aluminium ions accounted for a higher proportion of exchange sites in the deeper peat layers of the northern RA at Puutiosuo than at other sites. The amount of exchange sites occupied by Na^+, K^+ and NH_4^+ was small, as was that of Fe^{2+} for the most part. Only in the 0–5 cm surface layer of the southern RA at Kompsasuo did Fe^{2+} occupy more than 40% of the exchange sites (Table 1).

It can be estimated that about 4.6–5.8% of the peat cation exchange sites could be occupied by NH_4^+ in the OFAs (Table 3). In the case of the northern OFA at Kompsasuo this estimate is based on average ECEC values for the peat in 1991 and 1992. The NH_4^+ retention capacity of the peat in the different layers of the OFAs can be estimated to range from 0.18 to 0.77 g kg^{-1} dry peat.

The NH_4–N loading imposed on the Kompsasuo OFAs in 1987–1992 averaged 0.79 kg ha^{-1} d^{-1} in the northern and 1.84 kg ha^{-1} d^{-1} in the southern part, and that of the Puutiosuo OFAs in 1990–1992 0.36 kg ha^{-1} d^{-1} and 2.02 kg ha^{-1} d^{-1}, taking into account the areas actually utilized. Since the retention potential of the 0–25 cm surface peat layer in the OFAs ranges from 93 to 219 kg NH_4–N (Table 4), this implies a service life of under one year, or under half a year for the 0–15 cm surface layer, given the loadings and decreases in NH_4–N amounts stated in Table 4. It is assumed that the OFAs are not loaded during the three winter months, when the surface peat is mainly frozen.

DISCUSSION

The results show that Ca^{2+} and Mg^{2+} are the most important competitors with NH_4^+ for the exchange sites in the present OFAs. This implies that the estimation method presented by Lance (1972) for NH_4^+ adsorption is applicable also in the present material. According to Clymo (1983), these cations are often dominant in minerotrophic mires. The contributions of other ions, e.g. Al^{3+} and Fe^{2+}, to the CEC of peat may sometimes also be important, but they were not so in the OFAs where the NH_4^+ adsorption was estimated. Also Mn^{2+} could have occupied some exchange sites even though it was not included in the analyses. In the peat samples taken from the depth of 5–25 cm of the Puutiosuo RA the sum of cations including Al in the extract is probably an overestimate of ECEC because of the probable high amount of Al from nonexchangeable sources.

Table 4. Total NH_4–N retention capacity of the peat, average N loading and estimated NH_4–N retention service life of the overland flow areas by reference to the amounts actually retained in the areas

OFA/layer (cm)	Total NH_4–N retention capacity of peat (kg)	Average annual loading (kg) from the peat mining area* NH_4–N	Io.N†	Tot.N	Average decrease in NH_4–N amount (%)*	Service life in NH_4–N retention (y)
Kompsasuo northern						
0–5	29	340	610	830	70	0.1
0–15	108					0.5
0–25	195					0.8
Kompsasuo southern						
0–5	27	720	860	1350	46	0.1
0–15	98					0.3
0–25	158					0.5
Puutiosuo northern						
0–5	82	470	470	870	65	0.3
0–15	160					0.5
0–25	219					0.7
Puutiosuo southern						
0–5	30	570	670	900	25	0.2
0–15	60					0.4
0–25	93					0.7

*In 1987–1992 at Kompsasuo and in 1990–1992 at Puutiosuo.
†Io.N = inorganic nitrogen (NH_4–N + NO_3–N).

Unbuffered salt solutions added to acid organic soils release Al not only from exchange sites but also from nonexchangeable sources (Amedee and Peech, 1976; Khanna *et al.*, 1986). Gore and Allen (1956) found that exchangeable Fe in peat is largely in the Fe^{2+} state. The extent of the exchange sites occupied by Fe^{2+} was high in the southern RA at Kompsasuo, and also higher in the southern OFA of Kompsasuo than in the other OFAs studied. The values determined here for ECEC are generally within the ranges reported by Westman (1981) for virgin sedge mires all over Finland, while in some places higher values are recorded.

One consequence of the use of a peatland area as an OFA is an increase in peat CEC values and thus in the NH_4^+ retention capacity of the peat. The CEC values in all the peat profiles at the northern OFA of Kompsasuo, which had been used for 6 y, were higher than those in the RA. The results for the OFAs of Puutiosuo, which had been used for a shorter time, were the same in the surface 0–15 cm horizon. The main reason for the increase in the CEC values for peat in the OFAs is probably a decrease in peat acidity, which could be seen in the material. This is probably mainly due to the flow of the slightly acid drainage waters to the OFAs. In 1990–1992 the annual pH of the peat mining water averaged 5.9–6.2, which resulted in dissociation of active groups in the surface peat layer. The particulate and dissolved organic matter of the slightly acid peat mining waters retained on the OFAs is probably also not as acidic as in peat of the OFAs. The decrease in suspended solids from peat mining water averaged 70% in the northern OFA of Kompsasuo in June–October 1990–1991 (Ihme, 1994) and that of dissolved organic matter 21%. The amount of suspended solids retained during this time in the OFA was thus about 90 kg ha^{-1} and that of dissolved organic matter about 580 kg ha^{-1}. Suspended matter in the peat mining water has been mainly organic. The humic substances retained in the northern OFA of Kompsasuo seem to be mainly humic acids (Heikkinen and Ihme, 1994).

As compared to the decrease in peat acidity, the changes in the degree of peat humification seem not to have consistently affected the CEC values and the NH^+ retention capacity of peat. Nevertheless, Westman (1981) reported a negative relationship between ECEC and bulk density in peat from virgin sedge mires in Finland. Furthermore, CEC did not significantly ($p = 0.05$) correlate with the degree of humification in material collected from widely varying bog types in Finland (Puustjärvi, 1956). As a result of peat decomposition, the number of functional groups responsible for cation exchange and, hence CEC, increase.

The decreases in NH_4^+ amounts obtained in the OFAs of the southern parts of Kompsasuo and Puutiosuo were lower than those for the northern areas. In regard to the Kompsasuo peat, this can partly be explained by the lower NH_4–N retention capacity in the southern than in the northern OFA, but not at Puutiosuo. There are also other factors explaining the poorer purification results in the southern areas. The southern OFAs constitute smaller percentages of the adjacent catchment areas than the northern areas, and thus are more heavily loaded than their northern counterparts. There are also bypass flows due to the previous ditches in these areas. Because of these factors, the residence time of the peat mining water in the southern areas is too short and the contact with the peat too poor for the chemical processes leading to effective NH_4^+ retention.

The potential NH_4^+ retention capacity of the 0–15 cm surface peat gives the OFAs an approximate service life of under 6 months with the loadings imposed on the OFAs and 25–70% decreases in NH_4^+ of peat mining water measured here. The water tends to flow primarily in the surface 0–20 cm layer in the northern OFA at Kompsasuo (Ihme, 1994), and probably also in the other OFAs studied. The NH_4^+ adsorbed on the peat is, however, exchangeable, and the recent results from the northern OFA of Kompsasuo indicate that some of it can be mobilized from the area as a result of nitrification and subsequent N loss through denitrification. This probably explains why the peat could not be saturated with NH_4^+, and the duration of NH_4^+ retention by peat (service life) of the OFAs could be longer than the estimate presented here. The annual average decreases in NH_4^+ amounts in the northern OFAs of Kompsasuo and Puutiosuo, with the best purification results, have been continuously over 70% during their utilization times of 6 and 3 y, respectively (Ihme *et al.*, 1991; Ihme, 1994). It has been assumed that, owing mainly to the nitrification–denitrification processes, no decrease in N removal efficiency occurs at a given loading rate with continued application of household waste water to an area of peatland (Richardson and Nichols, 1985). The NH_4^+ adsorbed on peat can also be assimilated by plants (unpublished results) and peat microbes in the OFA. Hence, cation exchange capacity of OFA is an important property that contributes to surface water protection against eutrophication by N.

To ensure good purification results for NH_4^+, OFAs must be constructed so that the water comes into the closest possible contact with the peat. The decreases in the NH_4^+ amounts achieved depended to a great extent on the hydrology in the OFA. They have been generally smallest under high flow conditions (Ihme, 1994). The utilization rate for an OFA should be as high as possible. This can be achieved through an even distribution of water over the area. The area should not have ditches that cause bypass flows. Any hydrological changes occurring in the area as a consequence of “clogging” of the surface peat layer with suspended solids should be prevented by constructing a sedimentation basin above the OFA. Like the chemical retention, the efficiency of the most important biological processes leading to decreases in N amounts in OFAs (denitrification and assimilation by plants) can on the basis of published data (Patrick *et al.*, 1976; Stewart and Ornes, 1975) be supposed to depend on the contact of the peat mining water with peat.

CONCLUSIONS

Assuming that the NH_4^+ retention was attributable to the 0–15 cm surface peat layer alone, the calculated NH_4^+ retention potential of OFA peat should have lasted under 6 months with the loadings imposed on the OFAs and decreases in NH_4^+ amounts of peat mining water considered here. The actual duration of peat capacity to retain NH_4^+ in the OFAs has, however, already been shown in this research to be longer, and apparently will be so also in future, probably as a result of two processes: nitrification and subsequent N loss through denitrification, and biological assimilation.

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