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THE USE OF OVERLAND FLOW FOR THE PURIFICATION OF RUNOFF WATER FROM PEAT MINING AREAS

Raimo Ihme, Kaisa Heikkinen and Esko Lakso

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The use of peat for energy production has been increasing in Finland during the last few years and will continue to do so in the future. Runoff water from peat mining areas is currently purified mainly by means of sedimentation basins, basins of field ditches and retention pipes, although these have not always achieved a sufficient reduction in nutrient load in particular.

The aim of the present research is to examine the applicability of overland flow method in the purification of peat mining water. The overland flow method involves conducting the water from a peat mining area across a natural mire of a given size. An attempt was made to identify the most important factors contributing to the practicability of an overland flow area by studying a variety of sites. Full-scale field research was carried out in three peat mining areas in the province of Oulu in 1987—1989.

The results obtained from the northern overland flow area at the Kompsasuo peat mining site at Kuivaniemi indicated that it is possible to remove suspended matter, soluble organic matter and nutrients from peat mining water by means of a well-planned overland flow area. The average reduction of suspended matter in this area in summer and autumn was 44—74 %, that of organic matter 20—30 %, total N 38—74 %, NH_4—N 56—95 %, NO_3—N —10—93 %, total inorganic N 56—95 %, total P 37—68 %, PO_4—P 40—65 % and total Fe 9—56 %. It was possible to remove suspended matter better by means of an overland flow area than by using the sedimentation basin lying upstream of it or any of the sedimentation basins examined earlier. Sedimentation basins remove only a minor proportion of the nutrients from runoff water.

The results obtained in other overland flow areas, which were subjected to a higher load than that in the northern overland flow area at Kompsasuo, were usually poorer. Solids, organic matter and nutrients were often leached out of these areas. Their purification results were also impaired by bypass flows and, in the case of Murtosuo and Laakasuo, by contact between the runoff water and the mineral soil, which was mainly due to the thinness of the peat layer.

Planning, construction and maintenance instructions were drawn up on the basis of the investigations. Actual construction costs for the overland flow areas constituted 1—5 % of the maintenance costs for the peat mining area and were more or less equal to those for the sedimentation basin.

Further research should concentrate on establishing as exact planning, construction and operating instructions for the overland flow method as possible and on determining its reliability and the operating life of such an area.

Index words: peat production, runoff water, water pollution control, overland flow

1 INTRODUCTION

The use of peat for energy production has been increasing in Finland during the last few years and will continue to do so in the future. According to an energy policy programme established in 1983, attempts will be made to increase the use of peat as a source of heating energy to 20—30 million m^3 a year by 1995, i.e. to double the current level, and the use of peat for other purposes is also increasing. It has been estimated that, for maximum utilization, peatlands should be drained and prepared for production continuously at an average rate of 5 000—7 000 ha per year (Komiteanmietintö 1987). A considerable proportion of the peat resources in the country are located in the Province of Oulu, where an area of 10 000 ha was used for peat mining in 1988.

Peat mining results in changes in both the quantity and quality of the runoff water. Suspended matter from peat mining areas leaches into lakes and rivers during periods of high runoff in particular, and the leaching of soluble organic matter and nutrients may increase, involving the introduction of more ammonium nitrogen in particular into the runoff water than under natural conditions. Peat mining may also contribute significantly to local phosphorus load.

The water issuing from peat mining areas is currently purified mainly by means of sedimentation basins, and loading is further reduced by constructing the field ditches to slope as gently as possible and often providing the lower ends with sedimentation basins and retention pipes. It has nevertheless proved difficult to reduce the nutrient load in particular by means of the pollution control measures currently in use.

A research project "Development of water pollution control tehcnology in peat mining", to be carried out jointly by the Ministry of Trade and Industry, the peat producers, the water authorities, the Building Laboratory of the Technical Research Centre of Finland and the University of Oulu, was set up in spring 1987 as a result of the expansion in peat mining. The aim was to develop methods which would provide the most effective way of reducing the loading coming from mires at the various stages of preparation and mining, and to improve the methods already in use. The new methods examined in the project were peat filtration (Ihme et al. 1991a) and overland flow techniques (Ihme et al. 1991b).

The overland flow method involves conducting the water from a peat mining area across a natural mire of a given size, a method employed for household wastewater purification since 1950's. The method has been used earlier also for purifying the runoff water from certain peat mining areas in Finland, but there has been no previous research devoted to it. Experiences gained from the purification of household wastewater indicated that overland flow is an effective method for removing suspended matter and also soluble nutrients from wastewater (Surakka and Kämppi 1971, Boyt et al. 1977, Spangler et al. 1977, Tilton and Kadlec 1979, Guntenspergen et al. 1980, Dubuc et al. 1986, Goldstein 1986, Kent 1987, Kadlec 1987, Kadlec 1987, Kadlec and Hammer 1988).

The aim of the present research was to examine the suitability of the overland flow method for purifying the peat mining water. An attempt was made to identify the most important factors contributing to the practicability of an overland flow area by studying a variety of sites. Planning, construction and maintenance instructions were drawn up on the basis of the findings.

2 SITE DESCRIPTION

Research was carried out at two peat mining areas at the preparation stage, Kompsasuo in Kuivaniemi and Murtosuo in Pudasjärvi (Fig. 1), and at one peat mining area in full production, Laakasuo in Sotkamo, between 1987 and 1989.

2.1 The Kompsasuo peat mining area

The site was in a natural state until 1986 and was prepared for peat mining between 1986 and 1989 (Ihme et al. 1991b). Overland flow areas were constructed in the northern and southern parts of the site at the beginning of 1987, together with a sedimentation basin in the north. Sod peat was produced for about one week in summer 1988, and a total of approx. 1 000 m^3 during the following summer. Milled peat will be the main type to be collected from the area, although some sod peat will also be included. The entire mining site covers an area of 180 ha and is characterized by various Sphagnum-type peats with a mean humification of H 4.0 and a peat thickness of 1.5—5.0 m, the amount of peat available being approx. 2.3 million m^3. Water from the northern peat mining area is

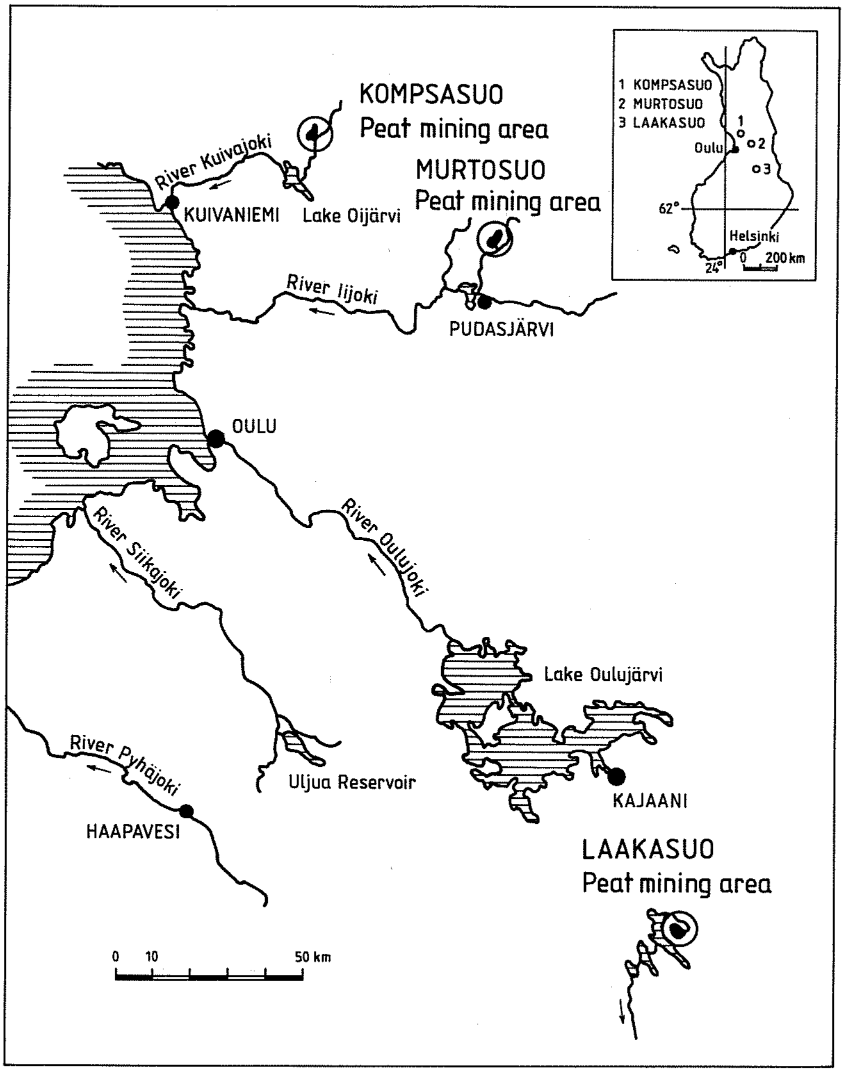

Fig. 1. Location of the sites.

conducted via the sedimentation basin and overland flow area into the River Hamarinjoki, from which it runs into the River Kuivajoki, while those from the southern one are conducted via the overland flow area to the Brook Karahkaoja and from there via River Kivijoki to Lake Oijärvi (Fig. 1, 2).

The northern overland flow area at Kompsasuo is a pine bog with swamp features in its lower part, and covers an area of approx. 2.4 ha (Table 1). The catchment area for the sedimentation basin and the overland flow area covers approx. 50 ha, i.e. the overland flow area constitutes 4.8 % of the catchment area. The gradient of the overland flow area is 8.0 ‰ and its peat thickness 1.9—3.1 m. The prevailing peat types are Menyanthes-Carex-Sphagnum peat occurring in the surface layer and Sphagnum-Carex peat found deeper down. The degree of humification in the 0—50 cm layer is between H1 and H4. Water flows from the peat mining area via the main ditch to the sedimentation basin and from there via the outlet ditch to the distribution ditch located in the upper part of the overland flow area (Fig. 2). The water is distributed over the overland flow area as evenly as possible by means of the distribution ditch, and the water which has flowed across the area is conducted to the outlet ditch below the area by means of the collection ditches. The exact dimensions of the ditches are presented in detail in a more extensive report (Ihme et al. 1991b). Water from the drainage basins located beyond the mining area is conducted past the sedimentation basin and overland flow area into the River Hamarinjoki.

The size of the southern overland flow area is approx. 1.9 ha (Table 1) while that of the peat mining area is 130 ha, i.e. the former, which has a gradient of 8.0 ‰, constitutes 1.5 % of the latter. The overland flow area has a peat thickness of over 3 m, the prevailing peat types being Carex-Sphagnum in the surface layer of 0—5 cm, Sphagnum-Carex between 5—15 cm and Carex peat at a depth exceeding 15 cm. The degree of humification was between H1 and H4 in the surface layer of 0—50 cm. Water flows from the peat mining area via the main ditch to the distribution ditch, by means of which it is distributed over the overland flow area (Fig. 2). Water guide boards were constructed in the area in June 1988. Water flows from the overland flow area to the collection ditch, the exact dimensions for which are presented in a more detailed report (Ihme et al. 1991b). Water flowing into the southern part of the area from the surrounding region has not been entirely isolated from that from the peat mining area.

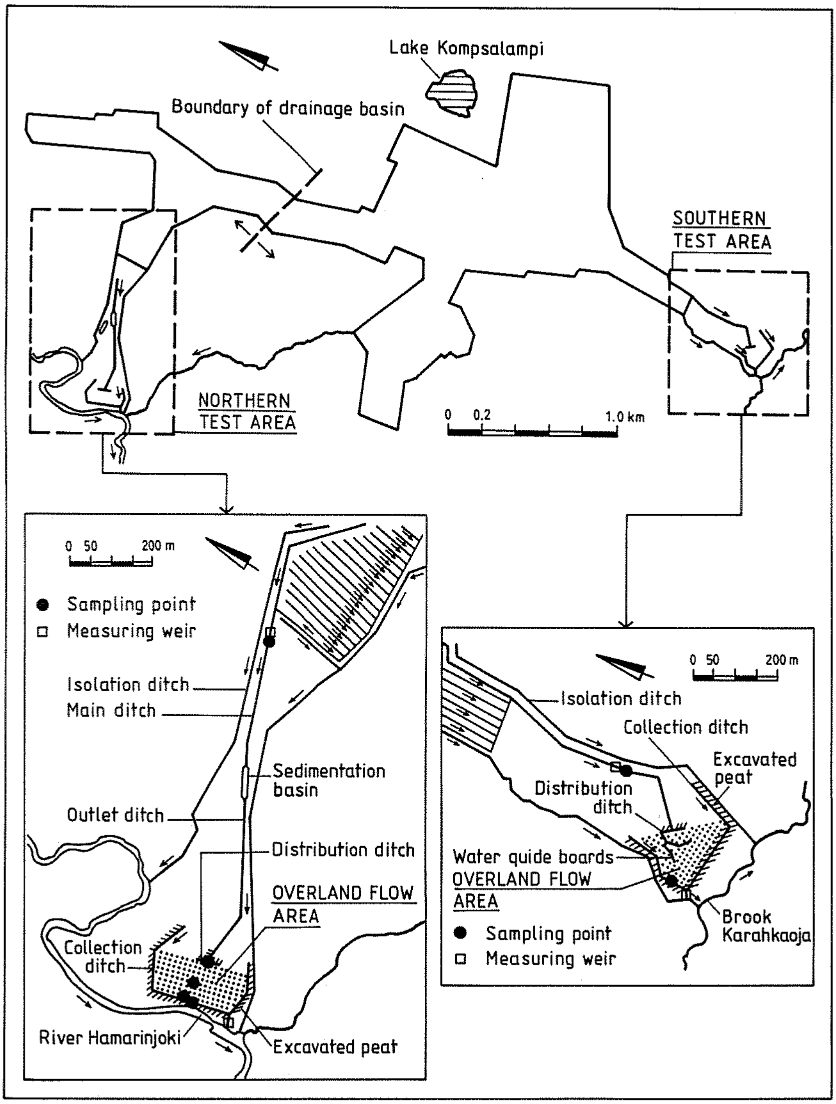

Fig. 2. Location of the overland flow areas, sedimentation basin, measuring weirs and water sampling points at the Kompsasuo peat mining area.

Table 1. Average seasonal reduction achieved using overland flow areas in the Kompsasuo, Murtosuo and Laakasuo peat mining areas between June and September 1987—1989, and factors affecting these reductions.

Parameter	Average reduction and factor affecting it			
	Kompsasuo1) northern	Kompsasuo1) southern	Murtosuo2)	Laakasuo3)
Reduction %				
SS	44—74	− 2—50	− 25—1	− 36—22
COD_{Mn}	20—30	12—26	− 1—1	− 77—(−10)
Tot. N	38—74	5—46	− 11—0	0—43
Inorg. N	56—95	40—81	− 49—16	18—71
NH_4—N	56—95	27—88	− 56—18	15—70
NO_3—N	−10—93	−591—36	−8—(−1)	44—94
Tot. P	37—68	− 33—43	21—26	− 20—(−13)
PO_4—P	40—65	− 90—42	16—19	−140—78
Tot. Fe	9—56	− 50—40	− 32—2	−310—(−76)
Hydraulic load $m^3\ ha^{-1}\ d^{-1}$	79—432	402—2 648	59—3 515	46—359
Load $kg\ ha^{-1}\ d^{-1}$				
SS	0.4 — 1.1	3.6 —12.5	3.8 —11.1	1.4 — 4.7
COD_{Mn}	3.0 —10.8	22.2 —62.0	16.9 —50.5	3.8 —16.9
Tot. N	0.2 — 0.9	1.0 — 2.8	0.8 — 1.4	0.3 — 1.3
NH_4—N	0.1 — 0.4	0.3 — 1.4	0.2 — 0.3	0.2 — 0.8
NO_3—N	0.01 — 0.2	0.03— 0.08	0.03— 0.04	0.01 — 0.07
Tot. P	0.004— 0.001	0.06— 0.14	0.02— 0.08	0.01 — 0.02
PO_4—P	0.001— 0.003	0.03— 0.08	0.01— 0.02	0.001— 0.003
Tot. Fe	0.2 — 0.5	1.5 — 5.5	2.1 — 5.4	0.7 — 2.1
Overland flow area				
Extent ha	2.4	1.9	0.8	2.4
% of drainage basin	4.8	1.55)	3.2	4.5 (5.7)6)
Average utilization rate %7)	60 —68	63 —70	67	31 —33
Utilized area as a % of drainage basin	2.8 — 3.3	0.9 — 1.0	2.1	1.4 — 1.5
Gradient ‰	8.0	8.0	7.0	20.0
Peat thickness m	1.9 — 3.1	> 3.0	0.5 — 2.0	0.1 — 0.2
Peat type	Sph, Sph-C	C-Sph, Sph-C	C-Sph	C-Sph
Peat humification	H1—H4	H1—H4	H1—H5	H1—H6
Obvious bypass flows	no	yes8)	yes	yes
Contact with mineral soil	no	no	yes	yes
Sedimentation basin above the area	yes	no	no	yes
Peat mining area				
Extent ha	50	130	25	42.4 (53.3)4)
Peat type	Sph	Sph	Sph	—
Peat mining stage	Prep.	Prep.	Prep.	Prod.

1) June-October 1987—1989, 2) June-August 1988—1989, 3) June-October 1988—1989, 4) entire drainage basin, 5) water flowing into overland flow area from outside peat mining area, 6) calculated from the drainage basin area used for production, 7) in 1988—1989, 8) reduced after installation of a water quide board, SS = suspended solids, Sph = Sphagnum, C = Carex, Prep. = preparation, Prod. = production

2.2 The Murtosuo peat mining area

The peat mining area to be constructed at Murtosuo consists of three sections which together form an area of 128.5 ha (Fig. 3). About 50 % of the area has been ditched for drainage purposes for various lengths of time from 1 year to 20 years. The overland flow area is located below section 3, the construction of which was started in autumn 1987 and the preparation work completed in 1988. This overland flow area was constructed in 1987, before the field ditches or main ditches. The area will be used for milled peat mining by means of Haku production method or harvesting method.

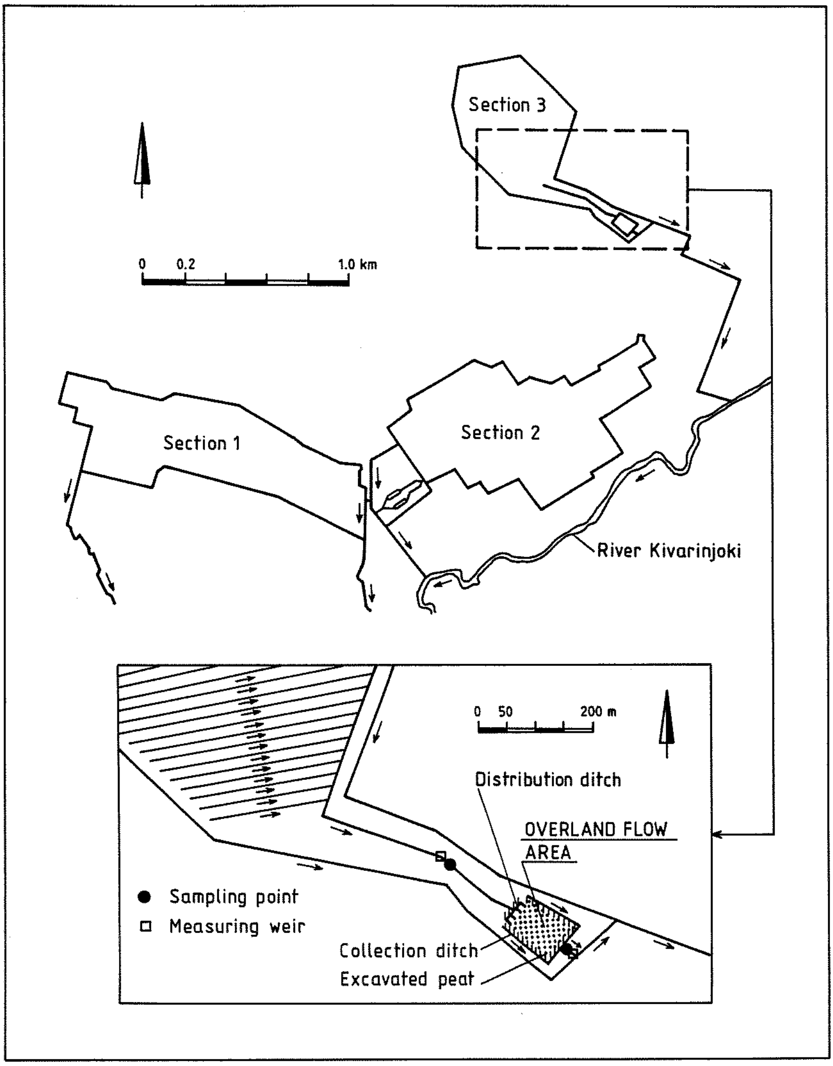

Fig. 3. Location of the overland flow area, sedimentation basin, measuring weirs and water sampling points at the Murtosuo peat mining area.

The mire is mainly composed of Carex-Sphagnum peat of an average humification of H 5.0 and average depth 2.1 m. The amount of natural peat available in the area is 3.2 million m^3. The sub-soil type of the area is till-like leached sand with occasional fine sand or silt. The water from the peat mining areas is conducted via sedimentation basins and the overland flow area into the River Kivarinjoki, from which it runs into Lake Kivarinjärvi and the River Törröjoki, finally reaching the River Iijoki (Figs. 1 and 3).

The overland flow area covers 0.8 ha (Table 1), and is mainly composed of pine bog. Its drainage basin is 25 ha in area, i.e. it constitutes 3.2 % of its entire drainage basin. Its gradient is 7 ‰. The peat thickness varies between 0.6 m and 2.0 m, the uppermost 0—5 cm consisting of Carex-Sphagnum peat which contains some dwarf-shrub material, while pure Carex-Sphagnum peat is found deeper down. The degree of humification is between H1 and H5 in the uppermost 0—5 cm. An existing drainage ditch in the overland flow area was plugged mechanically with a mixture of peat and mineral soil. Water from section 3 flows via a main ditch to the distribution ditch located in the upper part of the overland flow area, which distributes it over the whole area (Fig. 3). Four grids approx. 10.0 m in length were provided in the distribution ditch to spread the water more evenly. Once the water has flowed across the area, it is conducted via

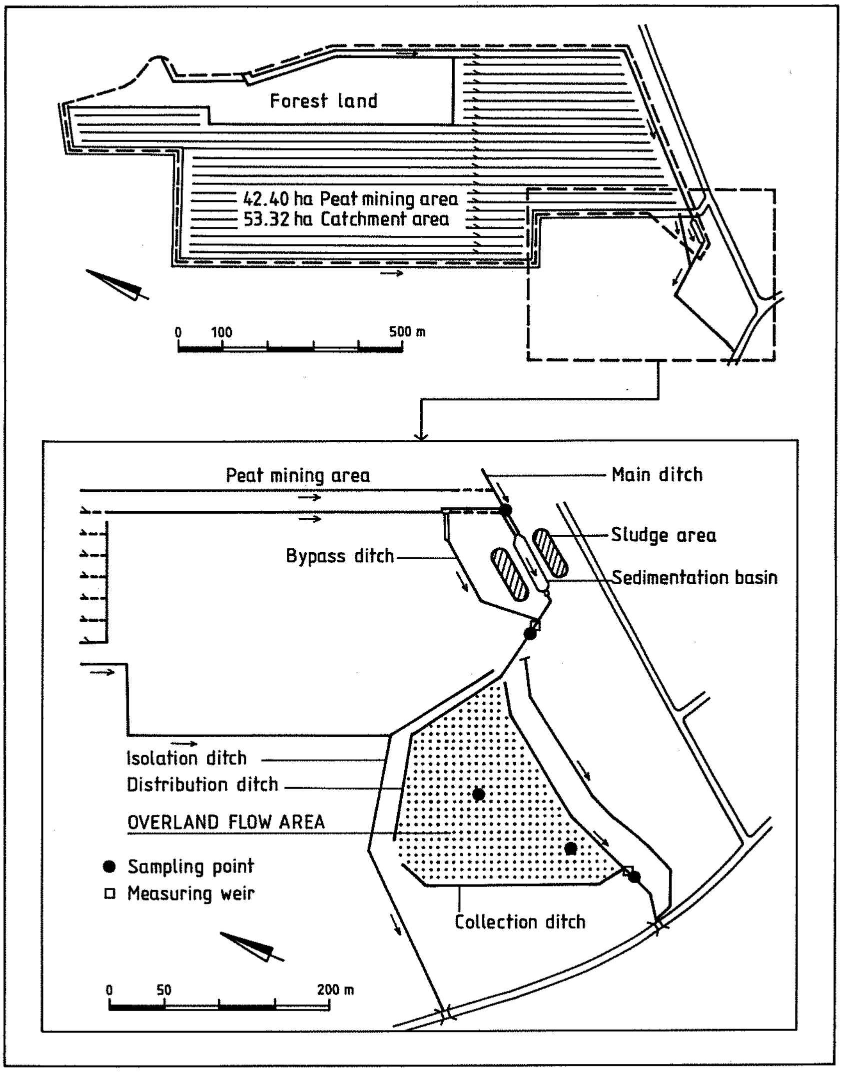

Fig. 4. Location of the overland flow area, sedimentation basin, measuring weirs and water sampling points at the Laakasuo peat mining area.

the collection ditches to the outlet ditch below. The peat lifted during the construction of the collection ditches was piled around the edges of the overland flow area to prevent any flow of water from the upper part of the area into the collection ditches. Water flowed into the mining area from elsewhere until October 1988.

2.3 The Laakasuo peat mining area

The Laakasuo peat mining is approx. 300 ha in extent (Fig. 4), and milled peat has been produced there since 1984. The average degree of peat humification is H 7.0, and the average peat depth when mining began was 2.7 m. Peat was lifted during June—August 1988, while preparation work was carried out in the summer and autumn of 1988, including the opening of drainpipes and cleaning of the main ditches and field ditches. Peat was lifted on a total of 44 days between May and August 1989, and preparation work similar to that carried out in 1988 again took place. Prior to the present investigations, the runoff water was processed in sedimentation basins. Water from the mining area flows mainly via the stream of Suopuro and the River Sopenjoki into Lake Laakajärvi, and some of it directly into the lake via a forest ditch.

The overland flow area is located in section 2 of the Laakasuo site (Fig. 4), which has a total area of 53.3 ha, of which 42.4 ha is subject to peat mining. Before the construction of the overland flow area below the sedimentation basin between April and May 1988 (Table 1), the water from section 2 was purified in the basin itself. The overland flow area covers 2.4 ha, i.e. 4.5 % of the drainage basin and 5.7 % of the peat mining area, and possesses features typical of a spruce mire. The peat layer is 0.1—0.2 m in thickness and is underlain by till. The centre of the area is 0.5—1.0 m lower than its edges, its longitudinal gradient being approx. 20.0 ‰. Eriophorum-Carex-Sphagnum peat occurs in the uppermost 0—5 cm, Carex-Sphagnum peat at depths of 5—15 cm, and Carex-Sphagnum peat with ligneous material below this. The degree of peat humification is H1—H6 in the layer 0—50 cm. Blocks (dams) were constructed in the old ditches at intervals of 10—20 m using soil from the area itself to prevent any bypass flows. The water flows from the peat mining area to the overland flow area via the main ditch, sedimentation basin, outlet ditch and distribution ditch (Fig. 4). The water which has flowed across the area is conducted to the outlet ditch below the area via the collection ditches, while runoff water from outside the peat mining area, apart from the 10.9 ha forest area within the same drainage basin, is conducted past the sedimentation basin and overland flow area to the lakes and rivers downstream.

3 MATERIAL AND METHODS

Full-scale field research was carried out at Kompsasuo between 29.7.1987 and 27.12.1989, at Murtosuo between 20.10.1987 and 27.12.1989 and at Laakasuo between 14.6.1988 and 20.12.1989.

Daily rain reports for Kompsasuo were supplied by the Meteorological Institute's observation station at Oijärvi, reports for Murtosuo by the corresponding unit at Kurenalus in Pudasjärvi and reports for Laakasuo by an observation station set up by Vapo Oy in the peat mining area itself. Flow rates were measured using triangular Thompson's measuring weirs constructed above and below the overland flow areas, some of them being equipped with a graphic water level recorder allowing continuous measurement.

Water samples were taken weekly from above and below the overland flow areas (Figs. 2, 3 and 4), and also from the main ditch above the sedimentation basin at sites which had such a basin. Samples were taken only during the warm season in 1987, but from 1988 onwards they were collected throughout the year from heat-insulated measuring weirs. The samples were examined for suspended solids, electrical conductivity, pH, colour, chemical oxygen demand (COD_{Mn}), total N, NH_4—N, total P, PO_4—P and total Fe content using methods employed by the water authorities (National Board of Waters 1981). In addition they were analyzed for suspended organic matter and NO_3—N content in 1988 and 1989. Following the flood period of 1989, samples from four points in the northern part of Kompsasuo, i.e. the main ditch above sedimentation basin, the distribution ditch, the seepage water from the area and the outlet ditch below the area, were examined for total P, total Fe and chemical oxygen demand after filtering through Whatman GF/C glass-filter paper of approximate pore size 1.2 μm. The purification results obtained were examined from subsets defined on a seasonal basis. The reductions achieved using the overland flow areas and sedimentation basins were calculated from the transport rates. Transport rates for 1987 were calculated from the mean runoff values for 1988 and 1989, as no runoff figures for 1987 were available. The differences between the sampling points in terms of the mean transport rates were evaluated using the t-test and the interrelationships between the water quality parameters and the reductions observed were examined by a correlation analysis. The dependence of concentrations on discharge was studied by regression analysis.

An annual vegetation survey was conducted in the overland flow area at the northern part of Kompsasuo and at Murtosuo and Laakasuo in the course of the present investigation. Quadrats of size 2 x 2 m^2 were established along three lines running parallel to the direction of flow, 4—7 quadrats per line. These were then examined in terms of the percetage cover of the tree, shrub and field layer species and the results classified on the basis of the substrate moisture and nutrient requirements of the various species according to Eurola and Kaakinen (1978).

The flow of water in the overland flow areas was observed in 1988 and 1989 to determine the rate of utilization of the areas. Suspended matter distribution within the area was monitored by means of collector boards installed beside the vegetation quadrats. In addition, peat samples were taken from depths of 0—5 cm, 5—15 cm and 15—50 cm at nine points in the northern overland flow area at Kompsasuo and at two points outside the area and were examined for electrical conductivity, pH, dry matter content, organic matter, total N, total P, total Fe, NH_4—N, NO_3—N and soluble P and Fe content, using methods employed in the Forest Research Institute (Halonen et al. 1983). Total N content was determined by the micro-Kjeldahl method (Kubin 1978).

4 RESULTS AND DISCUSSION

4.1 Hydrology

Annual precipitations during the three-year period were generally higher than the long-term averages. There were occasional downpours in the areas concerned, but also periods with less rain than average. Data was thus obtained from the various sites on the practicability of the overland flow technique under different rainfall conditions.

The monthly average runoffs for the northern peat mining area at Kompsasuo were 0.4—158.9 l s^{-1} km^{-2} in 1988—1989, while those for the southern area were 2.8—88.1 l s^{-1} km^{-2}, those for Murtosuo 1.4—168.9 l s^{-1} km^{-2} and those for Laakasuo 1.5—55.1 l s^{-1} km^{-2}. Runoff was greatest during the spring flood season and lowest in winter.

4.2 Water quality in the peat mining areas

The quality of the runoff water from the peat mining areas was similar to that in areas examined earlier (Table 2). Suspended matter was markedly high in some cases, and higher than in water issuing from natural mires, particularly at times of pronounced runoff.

The high content of humic substances in the peat mining water gave the water high colour and chemical oxygen demand values. The organic matter content was more or less equal to that observed in runoff water from natural mires. Most of the organic matter found in the peat mining water consists of humic substances. Approx. 94 % of all the organic matter in the runoff water from the northern peat mining area at Kompsasuo between July and December 1988 was of the "soluble" type.

The total Fe content of the runoff water was often virtually equal to that of natural mires (Table 2), although a considerable increase was observed occasionally. Most of the total Fe is bound to the humic substances, as also observed in other research into humic waterbodies (Ghassemi and Christman 1968, Koenings and Hooper 1979, Heikkinen 1990b). "Soluble" organic Fe constituted approx. 74 % of total Fe in the runoff water from the northern peat mining area of Kompsasuo between July and December, 1988.

Total N in the runoff water from the peat mining area of Murtosuo and from the northern and southern areas of Kompsasuo, which were at the preparation stage at the time of investigation, was practically equal to that in the water from natural mires (Table 2). A high total N content, however, was occasionally observed at Laakasuo, which was in full production. Inorganic N was in most cases markedly higher than in water from natural peatlands.

Total P and PO_4—P were mostly equal to the

Table 2. Average seasonal quality of runoff water from the peat mining areas discussed in the present paper and earlier, and that of natural mires examined earlier.

Parameter	Peat mining areas of the present research				Peat mining areas examined earlier	Natural mire
	Kompsasuo[1] northern	Kompsasuo[2] southern	Murtosuo[3]	Laakasuo[3]		
SS mg l^{-1}	3.1 — 18.4	3.4 — 8.8	5.3 — 10.4	11.5 — 35.3	2.0 —2 400[4, 8, 9]	1.2 —10.4[4]
COD_{Mn} mg l^{-1}	13.0 — 42.5	28.3 — 39.7	25.6 — 32.5	32.9 — 78.4	5.4 —134.0[4, 8, 9]	15.3 —86.0[4, 9, 11]
Colour Pt mg l^{-1}	140 —360	250 —350	220 —320	360 —740	—	—
Tot. N mg l^{-1}	1.5 — 4.1	1.0 — 1.8	0.8 — 1.6	2.9 — 5.0	0.9 — 4.7[4, 8, 9]	0.3 — 0.9[4, 9]
NH_4—N mg l^{-1}	0.90— 2.2	0.3 — 1.1	0.1 — 0.7	1.9 — 3.0	0.04 — 4.1[4, 8, 9]	0.02 — 0.1[4, 5, 6, 9]
NO_3—N mg l^{-1}	0.1 — 0.7	0.02— 0.05	0.02— 0.13	0.07— 0.16	0.01 — 1.0[4, 9]	0.001— 0.1[4, 5, 6, 9]
Tot. P mg l^{-1}	0.04— 0.08	0.06— 0.11	0.04— 0.06	0.04— 0.08	0.02 — 0.2[4, 8, 9]	0.02 — 0.09[4, 7, 9, 10]
PO_4—P mg l^{-1}	0.01— 0.07	0.04— 0.08	0.01— 0.02	0.01— 0.02	0.002— 0.2[4, 9]	0.007— 0.06[4]
Tot. Fe mg l^{-1}	1.6 — 7.1	1.9 — 4.2	3.4 — 5.1	7.4 — 13.6	1.2 — 10.0[4]	1.4 — 4.5[4]
pH	6.0 — 6.6	5.4 — 6.3	6.5 — 6.6	6.3 — 6.4	—	—

1) January—December 1987—1989, 2) June—October 1987—1989, 3) June—October 1988—1989, 4) Heikkinen 1990a), 5) Kenttämies (1979), 6) Hynninen ja Sepponen (1983), 7) Heikurainen et al. (1978), 8) Water Research Office of Northern Finland (1989), 9) Sallantaus (1983), 10) Kenttämies (1980), 11) Tolonen ja Hosiaisluoma (1978), SS = suspended solids

values observed in runoff water from natural mires, althought higher values were recorded in places (Table 2). Some of the P in humic water is bound to the humic substances (e.g. Jackson and Schindler 1975, Heikkinen 1990b). "Soluble" organic P constituted approx. 1/3 of the total P found in the runoff water from the northern peat mining area of Kompsasuo between July and December 1989.

The quality of the runoff water from peat mining areas and the flow of certain nutrients and other substances in it is discussed in more detail in a separate paper.

4.3 Load imposed on overland flow areas

4.3.1 Hydraulic load

The average hydraulic load imposed on the overland flow areas in summer and autumn was 46—3 515 m^3 ha^{-1} day^{-1} (Table 1), being lowest at Laakasuo and highest at Murtosuo, and the southern part of Kompsasuo. The load was usually considerably higher than that in the purification of household wastewater, $8.6 \cdot 10^{-4}$—38 m^3 ha^{-1} day^{-1} (Tilton and Kadlec 1979, Guntenspergen et al. 1980, Goldstein 1986, Kent 1987).

Owing to their gradients and some bypass flows, the areas were not operating in their entirety, but water crossed them only by certain routes (Table 1). It flowed mainly across the centre of the overland flow area in the northern peat mining area of Kompsasuo and across its right-hand side. The gradient of the southern overland flow area of Kompsasuo caused it to flow mainly down the right-hand edge. Here a plywood guide board was installed in 1988 to improve the distribution of water over a wider area, but there were obvious bypass flows in the area which could develop into small streams, particularly during rainy spells. Filling the original drainage ditch in the overland flow area of Murtosuo resulted to the development of some bypass channels in the area. Here water tended to flow along the line of the previous ditch and the other bypass cannels. In the case of Laakasuo, nearly all the water flowed via the ditches and, during drier periods in particular, mainly across the centre of the area as this was lower than the edges. The utilization rate of the overland flow area of Laakasuo, 31—33 %, was considerably lower at all seasons than that of the other areas.

The time for which the water was retained in the overland flow area, which was not examined in detail, is likely to have been longer in the northern part of Kompsasuo than at the other sites, as suggested by visual examination. The retention time is affected not only by the amount of water conducted to an overland flow area and the manner of flow, but also by the gradient of the area and evaporation in summer and ice formation in winter.

4.3.2 Suspended matter and nutrient load

The mean suspended matter, total N, total P, PO_4—P, total Fe and organic matter loads imposed between June and October on the northern overland flow area of Kompsasuo were lower than in the other areas (Table 1). The mean NH_4—N load was lowest at Murtosuo, but the values obtained did not always differ appreciably from those for Kompsasuo. The highest mean NO_3—N load was observed in the northern part of Kompsasuo. The loading values for overland flow areas are mainly affected by the hydraulic load, the concentrations of the various substances in the runoff water and the size of the area. Calculations on the basis of the utilization rate yielded markedly higher loading values than those acquired on the basis of the entire overland flow area in the case of Laakasuo in particular, where the average utilization rate was 31—33 %.

Assessments of the suspended matter distribution indicated that some parts of the overland flow areas were subjected to a higher load than others. Most of the suspended matter accumulated near the distribution ditch in the northern part of Kompsasuo, higher amounts being observed in the right-hand section.

The overland flow areas received higher mean suspended matter, NH_4—N and NO_3—N loads than those resulting from household wastewater purification (Ihme et al. 1991b). On the other hand, their highest mean total N and total P loads were lower than the highest corresponding values of 6.1 kg ha^{-1} day^{-1} and 0.4 kg ha^{-1} day^{-1} presented by Goldstein (1986) for the purification of household wastewater. The total P load caused by household wastewater elsewhere is usually below 0.05 kg ha^{-1} day^{-1} (Tilton and Kadlec 1979, Guntenspergen et al. 1980, Kent 1987), a value exceeded in the present investigation only in the case of the overland flow areas of the southern part of Kompsasuo and Murtosuo (Table 1).

4.4 Purification results

The results obtained from the northern overland flow area at Kompsasuo indicated that it is possible to remove suspended solids, soluble organic matter and nutrients from the peat mining water by means of a well-designed overland flow area (Table 1 and 3, Figs. 5, 6, 7, 8 and 9). As indicated by all the water quality parameters throughout the period 1987—1989, material flows below the overland flow area were highly significantly lower than those measured above the area (Table 3) and usually significantly or highly significantly, and always at least almost significantly, lower during each season.

The reductions for suspended matter, total P, PO_4—P, total Fe and organic matter in the northern overland flow area of Kompsasuo were almost equal in magnitude during the various seasons, even though no exact data were obtained on the spring flood period. The total mean removal of inorganic N was highest in summer

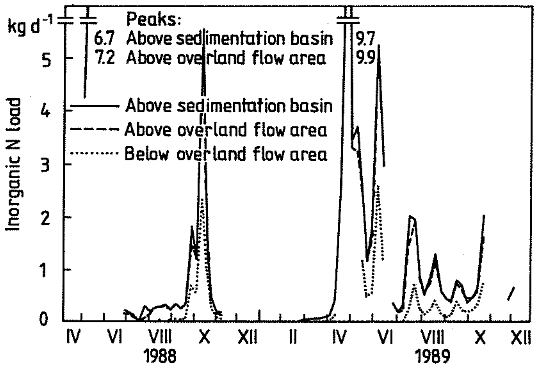

Fig. 7. Inorganic N load above the sedimentation basin and above and below the overland flow area in the northern part of the Kompsasuo peat mining area between 1987—1989.

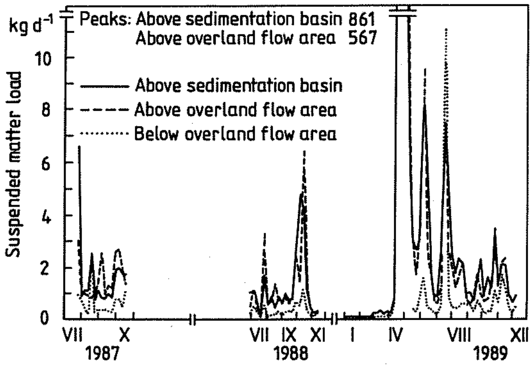

Fig. 5. Suspended matter load above the sedimentation basin and above and below the overland flow area in the northern part of the Kompsasuo peat mining area between 1987—1989.

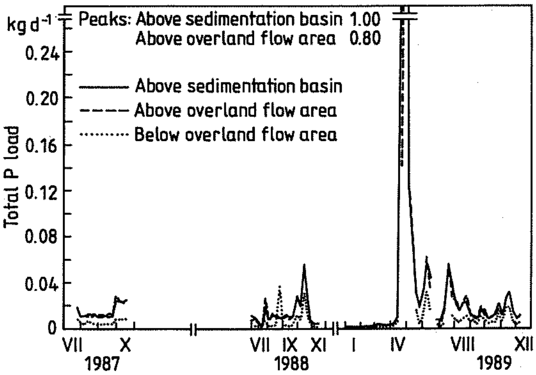

Fig. 8. Total P load above the sedimentation basin and above and below the overland flow area in the northern part of the Kompsasuo peat mining area between 1987—1989.

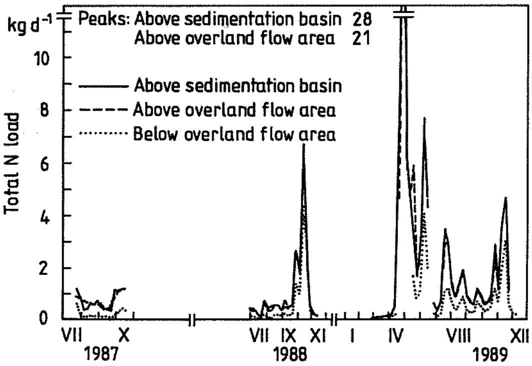

Fig. 6. Total N load above the sedimentation basin and above and below the overland flow area in the northern part of the Kompsasuo peat mining area between 1987—1989.

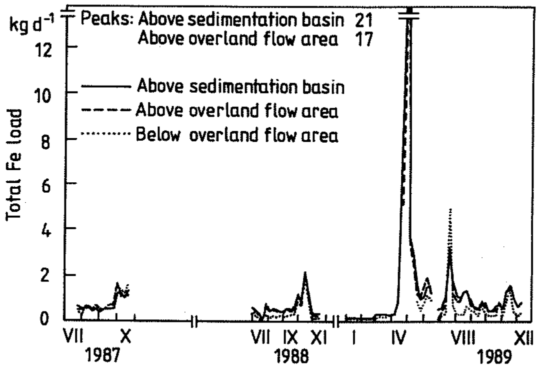

Fig. 9. Total Fe load above the sedimentation basin and above and below the overland flow area in the northern part of the Kompsasuo peat mining area between 1987—1989.

(62—95 %) and lowest in autumn (56—58 %), while the average removal of NH_4—N was highest in summer (80—95 %).

It was possible to remove suspended matter more efficiently by means of overland flow areas than using sedimentation basins, the suspended matter reductions of which are usually 30—40 % (Selin and Koskinen 1985) while no appreciable removal of nutrients is achieved. The northern overland flow area of Kompsasuo removed suspended matter, organic matter, total N, NH_4—N, NO_3—N, total P, PO_4—P and "soluble" organic P more efficiently than did the sedimentation basin above it. The average reductions achieved by means of the sedimentation basin between June and October were −34—36 % for suspended matter, 2—5 % for organic matter, −3—11 % for total N, −1—26 % for NH_4—N, −60—7 % for NO_3—N, —6—8 % for total P, —11—38 % for PO_4—P and —26—(—15) % for soluble organic P. Apart from autumn 1987, the mean reduction for total Fe was also higher in the overland flow area than in the sedimentation basin, which was −7—9 % for total Fe and −6—(−1) % for "soluble" Fe. These results indicate that nutrients and Fe often leached out of the sedimentation basin.

The use of a combination of a overland flow area and a sedimentation basin in the northern part of Kompsasuo almost invariably ensured a more efficient removal of suspended matter and nutrients than could have been achieved with a sedimentation basin or a overland flow area alone. The overland flow area succeeded in removing nutrients and organic matter even when leaching occurred in the sedimentation basin. Considerable amounts of suspended matter accumulated in the distribution ditch and the upper part of the overland flow area in the southern part of Kompsasuo, which had no sedimentation basin. Suspended matter can be dredged from a sedimentation basin if necessary, but this cannot be done in the case of a overland flow area. On the other hand, it is possible to reduce the amount of suspended matter accumulating in a overland flow area by means of a sedimentation basin, and thus to increase its operating life.

The average reduction for suspended matter achieved in the northern overland flow area of Kompsasuo in summer and autumn (44—74 %) was practically equal to that recorded in the purification of household wastewater, for which the reductions have usually been 60—90 % (Kent 1987, U.S. Environment Protection Agency Office of Research and Development 1988). As suggested by the biochemical oxygen demand values of 70—96 %, the removal of organic matter from household wastewater is effective (Surakka and Kämppi 1971, Kent 1987, U.S. Environment Protection Agency Office of Research and Development 1988). The present reductions for organic matter in the overland flow area were lower than those presented above, as indicated by chemical oxygen demand figures of 15—30 %. This is partly due to the considerable proportion of slowly degrading humic substances in the organic matter dissolved in the peat mining water, whereas most

Table 3. Statistical differences (t-test) between transport rates for given substances as recorded above and below the overland flow area. − = lower transport rate below the overland flow area, + = higher transport rate below the overland flow area.

Water quality parameter	Overland flow areas		
	Kompsasuo northern in 1988—1989	Kompsasuo southern June—October 1988—1989	Laakasuo June—October 1988—1989
Suspended solids	—***	—*	ND
COD_{Mn}	—***	—*	+***
COD_{Mn} in filtrates	—*** (s)1)		
Tot. N	—***	—***	—*
Inorganic N	—***	—***	—***
NH_4—N	—***	—***	—***
NO_3—N	—***	+**	—***
Tot. P	—***	ND	+*
PO_4—P	—***	ND	ND
Soluble organic P	—*** (s)1)		
Tot. Fe	—***	ND	ND
Fe in filtrates	—*** (s)1)		

1) year 1989, *** = significant at 0.1 % risk level, ** = significant at 1 % risk level, * = significant at 5 % risk level, ND = no difference, (s) = difference calculated on the basis of the results from seepage water from the area

of the organic matter contained in household wastewater degrades easily. Nitrogen reductions of over 80 % have usually been recorded in the case of the purification of household wastewater (Surakka and Kämppi 1971, Burke 1975, Boyt et al. 1977), while those observed in the northern part of Kompsasuo were lower, averaging 38—74 %. Correspondingly, the average reduction for total P from household wastewater has usually been 70—99 % (Surakka and Kämppi 1971, Burke 1975, Boyt et al. 1977), while the average rates at Kompsasuo were lower, 36—68 %.

The results obtained in the overland flow areas of Murtosuo, Laakasuo and the southern part of Kompsasuo were usually poorer than those in the northern Kompsasuo area (Tables 1 and 3), due to the fact that the load imposed on these areas was mostly higher (Table 1). The purification results obtained for their areas were further affected by bypass flows. The utilization rate at Laakasuo was low, only 31—33 %, while its gradient of 20 ‰ was markedly higher than that of the other overland flow areas (7—8 ‰). In the case of Murtosuo and Laakasuo, the runoff water was in contact with the mineral soil, due to the thinness of the peat layer and the presense of mineral soil deposits in the area.

4.5 Processes leading to reductions

Organic matter and nutrients are removed in overland flow areas by a process of sedimentation of suspended matter and retention in the vegetation. The reduction in chemical oxygen demand and total P correlated positively with that in suspended matter in all the overland flow areas examined. There was a positive correlation between the reduction of suspended matter and total Fe in the overland flow areas of Murtosuo, Laakasuo and the southern part of Kompsasuo. The variations recorded in the total N reduction were affected by the reduction of inorganic and organic N more than by that of suspended matter.

Denitrification is probably the most significant process contributing to the removal of inorganic N from runoff water in overland flow areas. The reduction of total inorganic N from the overland flow areas was always positive, except for Murtosuo. It has been estimated that at least 90 % of the NO_3—N coming from areas outside a mire escapes into the atmosphere by the process of denitrification (Bartlett et al. 1979). The total N reductions observed in the purification of household wastewater by means of overland flow have mainly been attributed to denitrification (Sloey et al. 1978), which may also play a major role in the case of Sphagnum peat bogs (Rock et al. 1984). The most significant factor reducing NH_4—N content may be nitrification. A negative correlation was in fact observed between the NH_4—N and NO_3—N reductions recorded in the overland flow areas of Kompsasuo. NH_4—N and NO_3—N can also be assimilated by the micro-organisms occurring in peat (Brooks and Zibilskie 1983, Coulson and Butterfield 1978), in addition to which NH_4—N ions may be retained in peat by means of ions exchange reactions (Burge and Broadbent 1961, Lance 1972). PO_4—P can also be assimilated by the micro-organisms in peat and bound chemically to peat, the role of the former been thought to be the more significant (Farnham and Brown 1972, Rock et al. 1984). The chemical binding of PO_4—P is further intensified by the Fe contained in the peat (Kaila 1959, Nichols and Boelter 1982) which is particularly high in minerotrophic mires (Clymo 1983), the type involved here. Finally, some of the "soluble" organic N, P and Fe is retained with humic substances in the overland flow area.

Nutrients are also retained in the vegetation of overland flow areas in the warm season. The results obtained from the present vegetational surveys and those carried out earlier in connection with the purification of household wastewater suggest that the removal of nutrients by harvesting the vegetation from the area would not be a profitable solution. Vegetational changes in overland flow areas are generally characterized by an increased vegetational coverage of the most humid site vegetation and reduced coverage of the driest site vegetation.

The chemical peat analyses carried out in the northern overland flow area of Kompsasuo provided no direct data on the loading on the peat as a result of overland flow, as even the rise of water level in a overland flow area will itself lead to various chemical changes in the peat.

4.6 Quality of the purified water

Most of the parameters used for evaluating water quality indicated that the water leaving the overland flow area of Kompsasuo was almost comparable in quality to that of the River Hamarinjoki which runs across the peat bogs onto which this runoff water flows (Table 4). Mean Fe concentrations during winter and the spring flood season were higher than in the River Hamarinjoki,

Table 4. Average water quality in the outlet ditch below the northern overland flow area of Kompsasuo, and in the River Hamarinjoki, into which the runoff water flows, measured between April—December 1989.

Water quality parameter	Runoff water	River Hamarinjoki
Suspended solids mg l^{-1}	1.8	1.9
COD_{Mn} mg l^{-1}	25.9	24.2[1]
Colour Pt mg l^{-1}	170	160
Tot. N $\mu g\ l^{-1}$	1 500	550
NH_4—N $\mu g\ l^{-1}$	240	11
NO_3—N $\mu g\ l^{-1}$	440	23[2]
Tot. P $\mu g\ l^{-1}$	21	32[1]
PO_4—P $\mu g\ l^{-1}$	9	11[1]
Tot. Fe mg l^{-1}	2.0	1.4[1]
Electrical conductivity mS m^{-1}	6.6	4.2[1]
pH	6.3	6.5[1]

[1] May—November, [2] May—June

however, and the mean N content was also markedly higher, though considerably lower than originally in the unpurified peat mining water.

5 PLANNING, CONSTRUCTION, MANAGEMENT AND COSTS OF OVERLAND FLOW AREAS

5.1 Research required before construction of an overland flow area

A feasibility survey must be carried out at the site before drawing up the necessary plans and constructing the overland flow area. This can be done in connection with investigations required for the ditching work to be performed in the peat mining area.

The survey should define the gradient and evenness of the area, the vegetation, the location of earlier ditches and that of the nearest mineral soil, the peat type, the degree of humification and the soil type below the peat layer. In addition the catchment area and gradient of the overland flow area should be examined, together with any inflow of water from beyond the area, the groundwater table and the depths of the lakes and rivers below the area, particularly during the flood season. All the longitudinal and cross-sectional measurements and soil surveys necessary for the planning and construction of the distribution ditches, collection ditches, isolation ditches, main ditches and measuring weirs should be carried out on the site.

Factors to be taken into consideration when establishing a location for an overland flow area are the possible need to enlarge it in the future and the construction of a reserve area. In addition, allowance should be made for the construction of a sedimentation basin above the overland flow area.

5.2 Dimensions of overland flow areas

Experiences gained so far from the northern overland flow area of Kompsasuo have indicated that overland flow areas function well provided that the following requirements are taken into consideration:

1. The overland flow area should amount to at least 2 % of the drainage basin and that its utilization rate should then be close to 100 %.
2. The drainage basin does not need to be very large. Small overland flow areas are easier to use and manage than large ones, in addition to which large, continuous areas are not always available.
3. The utilization rate for the overland flow area should be close to 100 %, i.e. it should be possible to distribute the water evenly over the area both longitudinally and laterally.
4. The gradient should be less than 1 %.
5. The area should be in as near a natural state as possible. The area should have no ditches which could cause bypass flows.
6. The peat should be over 1.0 m in thickness and as homogeneous as possible. The overland flow area will then sink evenly without any bypass flows being created. The ditches constructed around the area should not be extended to mineral soils capable of conducting water.
7. The prevailing peat type in the area should be Sphagnum peat with as low a degree of humification as possible.
8. The overland flow area should be dominated by a wetland vegetation (e.g. Carex sp. and Menyanthes).
9. The hydraulic load should be less than 500 m^3 ha^{-1} day^{-1} during the frost-free season.
10. The average suspended matter and nutrient loads on the overland flow field during the

frost-free season should be:

- less than 1.1 kg ha^{-1} day^{-1} for suspended matter
- less than 10.8 kg ha^{-1} day^{-1} for chemical oxygen demand
- less than 0.9 kg ha^{-1} day^{-1} for total N
- less than 0.013 kg ha^{-1} day^{-1} for total P
- less than 0.5 kg ha^{-1} day^{-1} a for total Fe

11. Water can be distributed over the entire overland flow area as evenly as possible by means of a distribution ditch of depth 1.5 m, width of bottom 1.2 m and gradient 1:1.0 dug into the peat. The process can be further improved by constructing grids in the distribution ditch. The excavated material should not be placed on the overland flow area but above the distribution ditch and a sufficient distance away from it.
12. The water which has flowed across the overland flow area is conducted away by the collection ditches into the lakes and rivers below the area. The ditches, dug in the peat, should be of depth 1.0 m, width of bottom 0.5 m and gradient 1:1.0. The excavated material can be used to construct an embankment close to the collection ditch on the edges of the overland flow area, if necessary to prevent possible bypass flows, and should be distributed in such a way as to allow the natural state of the peat layer to be preserved as much as possible. Should no such embankment be necessary, the material should be piled up outside the area a sufficient distance away from the collection ditch.
13. Where necessary, bypass flows should be prevented by means of guide boards of size 1.2·2.5 m^2 constructed of overlapping sheets of 12 mm plywood, for example, and embedded into the area, taking note of the gradients in the area.
14. Any water coming from outside the peat mining area should be conducted past the overland flow area via isolation ditches.
15. There should be a sufficient altitude difference between the peat mining area and the overland flow area to prevent the latter from blocking the passage of water from the former. Water can also be conducted to the overland flow area by pumping, however.
16. The overland flow area should be located so that it is not affected by the flood water accumulating in the lakes and rivers below it in spring.
17. A sedimentation basin should be constructed above the overland flow area to reduce the load imposed on it.
18. Enough space should be provided to allow the distribution ditch in the overland flow area and the sedimentation basin to be dredged, and a separate area should be made available for storing the resulting sludge.

5.3 Construction of overland flow areas

The overland flow area and all the related structures should be established at their final positions before the ditching required for preparatory draining of the mire and the draining proper is undertaken. Most of the work should be carried out in winter, when the bearing capacity of the soil is highest and both drainage and erosion loading are low, and finished off during the following summer if necessary.

5.4 Maintenance of overland flow areas

The distribution ditch and sedimentation basin located above the area should be dredged regularly, at least once a year, depending on production levels, rainfall, the gradient of the field ditches and the condition of the sedimentation basins of field ditches, for example. The condition of the ditch network and sedimentation basin must be inspected regularly and all possible defects repaired. The overland flow area must be kept as much in its natural state as possible, and not be interfered with unnecessarily. Machines should not be used in the area as they may easily create bypass flow channels and cause the sludge which has accumulated in the area to move. The area should be provided with an easy access with a view to the maintenance of it and its related constructions.

5.5 Costs

Overland flow can be considered a relatively inexpensive method of water purification. As-

Table 5. Costs involved in the construction and maintenance of the northern and southern overland flow areas of the Kompsasuo peat mining area and those at Murtosuo and Laakasuo peat mining areas.

Overland flow area	Costs[1] FIM ha^{-1} a^{-1}	Construction costs[2] FIM ha^{-1}
Kompsasuo, northern	470	1 600
Kompsasuo, southern	155	460
Murtosuo	660	1 500
Laakasuo	600	1 700

[1] calculated using a balanced annuity method with an assumed operating life of 10 years and an interest rate of 11 %, [2] excluding maintenance costs

suming that an overland flow area was used for 10 years at an interest rate of 11.0 %, the total annual building and maintenance costs per hectare of peat mining area would be 155—660 FIM ha^{-1} a^{-1} (Table 5). These calculations are based on the 1988 price levels and include costs arising from the surveys performed preceding the construction of the area, the measurements, piling work, land clearance work, levelling of the surface, and the construction of ditches, measuring weirs and limnigraphs. Annual maintenance costs are assumed to be 10 000 FIM for each overland flow area. Land acquisition costs are not included.

The construction costs for an overland flow area are approximately equal to those for a sedimentation basin. The actual construction costs of the overland flow areas discussed here constituted 1—5 % of the management costs of the entire peat mining area. Costs are admittedly affected by various local conditions such as the location of the overland flow area with respect to the peat mining area.

6 NEED FOR FURTHER RESEARCH

Future investigations should concentrate on establishing as exact planning, construction and operating instructions as possible for prospective users of the overland flow method and providing data on the reliability and operating life of such areas. Research should be continued in functioning overland flow areas at peat mining sites at both the preparation and production stage.

The most significant factors contributing to the purification capacity of overland flow areas should be identified in order to provide a more detailed basis for their dimensioning. The hydrology of overland flow areas already in operation should be examined, together with factors affecting the retention of suspended solids and nutrients. This lies beyond the scope of the present paper, however, which focuses on the loads of various substances transported into overland flow areas or leaching out of them. The hydrology of overland flow areas was similarly not examined in detail.

Before any very extensive use is made of overland flow areas, their long-term operability (10—20 years) should also be examined. A model should be developed for evaluating the operating life and purification capacity of overland flow areas which would be able to account for the most significant retention processes and factors affecting these. Data on the operation of a overland flow area can also be provided by long-term monitoring. In addition, more accurate data are required on the operation of overland flow areas during flood periods, and management and maintenance methods should be developed to improve their operation.

7 SUMMARY

The use of peat for energy production has been increasing in Finland during the last few years and will continue to do so in the future, and a considerable proportion of Finland's peat resources are located in the Province of Oulu. Peat mining causes suspended matter and nutrients to leach into the lakes and rivers below the site, on account of which the peat mining water is currently purified mainly by means of sedimentation basins and loading further reduced by constructing the field ditches to slope as gently as possible and often providing the lower ends with sedimentation basins and retention pipes. It has nevertheless proved difficult to reduce the nutrient load in particular by means of the pollution control measures currently in use.

A research project "Development" of water pollution control technology in peat mining", to be carried out jointly by the Ministry of Trade and Industry, the peat producers, the water authorities, the Building Laboratory of the Technical Research Centre of Finland and the University of Oulu, was set up in spring 1987 as a result of the expansion in

peat mining. The aim was to develop methods which would provide the most effective way of reducing the loading coming from mires at the various stages of preparation and mining, and to improve the methods already in use. The new methods examined in the project were peat filtration and overland flow techniques.

The overland flow method involves conducting the water from a peat mining area across a natural mire of a given size and has earlier been applied to the purification of household wastewater, good results having been obtained in the removal of both suspended matter and nutrients. The method has been used earlier also for the purification of runoff water from some peat mining areas in Finland, but no research was carried out into this.

The aim of the present work was to examine the suitability of the overland flow method for the purification of peat mining water. An attempt was made to identify the most important factors contributing to the practicability of a overland flow area by studying a variety of sites. Planning, construction and maintenance instructions were drawn up on the basis of the findings.

Full-scale field research was carried out in three peat mining areas in the Province of Oulu in 1987—1989. Of these, Kompsasuo at Kuivaniemi and Murtosuo at Pudasjärvi were at the preparation stage and Laakasuo at Sotkamo in full production. Two overland flow areas, northern and southern were examined at Kompsasuo. There was a sedimentation basin for water purification above the overland flow area in the northern part of Kompsasuo and at Laakasuo.

The overland flow areas were 0.8—2.4 ha in size, constituting 1.5—4.8 % of the drainage basins of the peat mining areas. The northern overland flow area at the Kompsasuo peat mining area is a pine bog with swamp features in its lower part, and the overland flow area of the Murtosuo peat mining area is also a pine bog, whereas that of the Laakasuo peat mining area contains features typical of a spruce mire. The gradient of the overland flow area is 8.0 ‰ in the northern and southern parts of Kompsasuo, 7.0 ‰ at Murtosuo and 20.0 ‰ at Laakasuo. The northern and southern parts of Kompsasuo have a peat layer of over 1.9 m, Murtosuo 0.6—2.0 m and Laakasuo 0.1—0.2 m. The overland flow areas in the northern and southern parts of Kompsasuo are characteristically composed of Carex-Sphagnum peat and Sphagnum-Carex peat and those at Murtosuo and Laakasuo of Carex-Sphagnum peat. The degree of humification in the uppermost 0—50 cm is H1—H4 in the northern and southern parts of Kompsasuo, H1—H5 at Murtosuo and H1—H6 at Laakasuo.

Flow rates were measured using triangular Thompson's measuring weirs, constructed above and below the overland flow areas, some of them being equipped with a limnigraph allowing a continuous measurement. The water samples were obtained from above and below the overland flow area in the summer and autumn of 1987 and weekly throughout the year after 1988, and from the main ditch at sites with a sedimentation basin. They were analysed for suspended matter, organic matter and nutrient content. The results were examined from subsets defined on a seasonal basis. Reductions achieved by means of the overland flow areas and sedimentation basins were calculated from the transport rates. Annual vegetation surveys were carried out in the overland flow areas of Murtosuo, Laakasuo and the northern part of Kompsasuo. Utilization rates were determined for the overland flow areas in 1988 and 1989. Suspended matter retention was measured by means of collector plates. Peat samples were also obtained from the northern overland flow area of Kompsasuo in September 1989 and analysed for their organic matter and nutrient content.

Data were obtained on the functioning of the overland flow area under varying rain conditions during the three-year period. The average hydraulic load imposed on the areas in summer and autumn was 46—3 515 m^3 ha^{-1} day^{-1}. Owing to their gradients and to some escape of water due to bypass flows, these areas were not operating in their entirety, but water crossed them only by certain routes. Utilization rates in 1989 were 60 % for the northern part of Kompsasuo and 63 % for the southern part, 67 % for Murtosuo and 31 % for Laakasuo.

The average suspended matter load imposed on the overland flow areas in summer and autumn was 0.4—12.5 kg ha^{-1} day^{-1}, that for organic matter 3.0—62.0 kg ha^{-1} day^{-1}, total Fe 0.2—5.5 kg ha^{-1} day^{-1}, total N 0.2—2.8 kg ha^{-1} day^{-1} and total P 0.004—0.14 kg ha^{-1} day^{-1}. An average suspended matter, nutrient and organic matter load lower than that for the other overland flow areas examined was usually recorded in the northern overland flow area of Kompsasuo between June and October, while the area had the highest average NO_3—N load. Loading values markedly higher than those calculated on the basis of the entire overland flow area are obtained especially in Laakasuo using an area determined from the utilization rate.

The results obtained in the northern overland flow area of Kompsasuo indicate that it is possible to remove suspended matter, soluble organic matter and nutrients from peat mining water by means of a properly planned overland flow area. The average reduction of suspended solids in this area in summer and autumn was 44—74 %, being 20—30 % for organic matter, 38—74 % for total N, 56—95 % for NH_4—N, —10—93 % for NO_3—N, 56—95 % for total inorganic N, 37—68 % for total P, 40—65 % for PO_4—P and 9—56 % for total Fe. It was possible to remove suspended matter better in the overland flow area than in the sedimentation basin located above it or in any of those examined earlier. Similarly, sedimentation basins did not prove very effective for the removal of nutrients.

The results obtained in the overland flow areas of the southern part of Kompsasuo, Murtosuo and Laakasuo were usually poorer than those for the northern overland flow area of Kompsasuo, due to the fact that the load imposed on these areas was generally higher. Their purification results were further impaired by bypass flows, with suspended matter, organic matter and nutrients often being leached out of the areas, and by the contact between the runoff water and the mineral soil in the overland flow areas of Murtosuo and Laakasuo, resulting mainly from the thinness of peat layer.

Organic matter and nutrients are removed from peat mining water with the suspended matter retained in the overland flow area. Most inorganic N is presumably removed from the areas by the process of denitrification, while nitrification is probably the most significant process reducing NH_4—N concentrations. NH_4—N, and NO_3—N and PO_4—P can also be assimilated by the microorganisms found in peat. Some of the organic N, P and Fe is retained with humic substances. Nutrients are retained also by the vegetation in the warm season. The results obtained from vegetational surveys carried out in the overland flow areas examined here and in connection with the purification of household wastewater earlier suggest that the removal of nutrients by harvesting the vegetation from the area would not be a profitable solution.

Planning, construction and maintenance instructions were drawn up for overland flow areas on the basis of the site investigations. Surveys need to be carried out before plans are drawn up for an overland flow area and its construction. Experiences gained in the northern part of Kompsasuo indicate that a overland flow area should constitute at least 2 % of the catchment area and that its utilization rate should then be close to 100 %. The water conducted to the area should be distributed evenly over the entire overland flow area, which should be in as near natural a state as possible, and should not have any previous ditches that could cause bypass flows. The peat in the area should be as homogeneous as possible, and at least 1.0 m in thickness throughout. It should be predominantly Sphagnum peat with as low a degree of humification as possible, and posses a dense wetland vegetation. The hydraulic load during the frost-free season should be less than 500 m^3 ha^{-1} day^{-1}. Recommended values were also assigned for the suspended matter, nutrient and organic loads to be imposed on the area. The water should be distributed over the entire overland flow area as evenly as possible by means of a distribution ditch and conducted to the lakes and rivers below the area by collection ditches. Any water flowing from outside the area should be conducted past it via isolation ditches, which should not extend down to the water-conducting mineral soil layers. A sedimentation basin should be constructed above the overland flow area. The overland flow area and all the necessary structures should be established at their final sites before the ditching work belonging to the preparatory drainage phase or the drainage proper is undertaken. The distribution ditch and sedimentation basin above the overland flow area should be cleaned when necessary, and at least once a year. The overland flow area should be preserved in its natural state as far as possible and provided with easy access for maintenance purposes.

The actual construction costs of overland flow areas discussed here constituted 1—5 % of the management costs of the peat mining areas, being practically equal to those of a sedimentation basin.

Future investigations should concentrate on establishing as exact planning, construction and operating instructions as possible for prospective users of the overland flow method and providing data on the reliability and operating life of such areas. Research should be continued in functioning overland flow areas at peat mining sites at both the preparation and production stage. The most significant factors contributing to the purification capacity of overland flow areas should be identified to provide a more detailed basis for their dimensioning. The hydrology of overland flow areas already in operation should be examined, together with factors affecting the retention of suspended solids and nutrients. Before any extensive use is made of overland flow areas, their long-term operational characteristics (over 10—20 years) should be examined. Their behaviour at times of flooding should also be examined in more detail, and more should be done to develop preparation and maintenance methods.

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YHTEENVETO

Turpeen käyttö maamme energiantuotannossa on viime vuosina lisääntynyt ja tulee edelleen lisääntymään. Huomattava osa maamme turvetuotantoalueista sijaitsee Oulun läänissä. Turvetuotanto lisää kiintoaineen ja ravinteiden huuhtoutumista alapuoliseen vesistöön. Turvetuotantoalueelta valuvia vesiä on puhdistettu nykyisin lähinnä laskeutusaltaiden sekä sarkaoja-altaiden ja päisteputkipidättimien avulla. Käytössä olevilla vesiensuojelurakenteilla ei varsinkaan ravinnekuormitusta ole voitu aina pienentää riittävästi.

Keväällä 1987 käynnistettiin tutkimusprojekti "Turvetuotannon vesiensuojeluteknologian kehittäminen" kauppa- ja teollisuusministeriön, turvetuottajien, vesiviranomaisten, Valtion teknillisen tutkimuskeskuksen rakennuslaboratorion ja Oulun yliopiston välisenä yhteistyönä. Tavoitteena oli kehittää menetelmiä, joiden avulla voidaan mahdollisimman tehokkaasti vähentää suolta tulevaa kuormitusta tuotannon ja kuntoonpanon eri vaiheissa. Lisäksi tarkoituksena oli parantaa jo käytössä olevia menetelmiä. Projektissa tutkittavia uusia menetelmiä olivat pintavalutus ja turvesuodatus.

Pintavalutuksella tarkoitetaan turvetuotantoalueelta tulevan veden valuttamista tietynsuuruisen luonnontilaisen suoalueen yli. Menetelmää on aikaisemmin käytetty lähinnä asutuksen jätevesien puhdistukseen, jolloin sekä kiintoaineen että ravinteiden poistossa on saatu hyvät tulokset. Menetelmällä on puhdistettu aikaisemmin myös joidenkin turvetuotantoalueiden valumavesiä, mutta tutkimuksia näiden vesien puhdistamisesta ei ole aikaisemmin tehty.

Tämän tutkimuksen tavoitteena oli määrittää pintavalutuksen soveltuvuus turvetuotannon valumavesien puhdistukseen. Erilaisten kohteiden avulla pyrittiin määrittämään pintavalutuskentän toimivuuteen vaikuttavat tärkeimmät tekijät. Tutkimusten perusteella laadittiin pintavalutuskentän suunnittelu-, rakentamis- ja kunnossapito-ohjeet.

Täysmittakaavaiset kenttätutkimukset tehtiin vuosina 1987—1989 kolmella eri turvetuotantoalueella, jotka sijaitsevat Oulun läänissä. Näistä Kuivaniemen Kompsasuo ja Pudasjärven Murtosuo olivat kunnostusvaiheessa ja Sotkamon Laakasuo tuotantovaiheessa. Kompsasuolla tutkittiin kahta eri pintavalutuskenttää. Kompsasuon pohjoisosassa ja Laakasuolla oli pintavalutuskentän yläpuolella lisäksi myös laskeutusallas vesienkäsittelyrakenteena.

Pintavalutuskenttien pinta-alat olivat 0,8—2,4 ha, ja niiden osuus on 1,5—4,8 % yläpuolisen turvetuotantosuon valuma-alueen pinta-alasta. Kompsasuon pohjoinen pintavalutuskenttä on suotyypiltään rämettä ja kentän alaosassa ilmenee luhtaisuuden piirteitä. Myös Murtosuon pintavalutuskenttä on suotyypiltään rämettä, kun taas Laakasuon pintavalutuskentällä on korpisuuden piirteitä. Kentän kaltevuus on Kompsasuon pohjois- ja eteläosassa 8,0 ‰, Murtosuolla 7,0 ‰ ja Laakasuolla 20,0 ‰. Kentän turvekerroksen paksuus on Kompsasuon pohjois- ja eteläosassa yli 1,9 m, Murtosuolla 0,6—2,0 m ja Laakasuolla 0,1—0,2 m. Pintavalutuskentän turve on Kompsasuon pohjoisosassa sararahka- ja rahkasaraturvetta, Kompsasuon eteläosassa sararahka- ja rahkasaraturvetta ja Murtosuolla sekä Laakasuolla sararahkaturvetta. Turpeen maatuneisuusaste 0—50 cm pintakerroksessa on Kompsasuon pohjois- ja eteläosassa H1—H4, Murtosuolla H1—H5 ja Laakasuolla H1—H6.

Virtaamat mitattiin pintavalutuskenttien ylä- ja alapuolelle rakennetuilla Thompsonin kolmiomittapadoilla. Osa mittapadoista oli varustettu piirtävällä vedenkorkeusmittarilla, jolloin virtaamat saatiin mitatuiksi jatkuvina. Vesinäytteet otettiin vuonna 1987 kesällä ja syksyllä ja vuodesta 1988 lähtien koko vuoden ajan viikottain pintavalutuskentän ylä- ja alapuolelta. Kohteissa, joissa oli laskeutusallas, näytteet otettiin myös laskeutusaltaan tulouomasta. Näytteistä määritettiin kiintoaineksen, orgaanisten ainesten ja ravinteiden pitoisuudet. Tulokset käsiteltiin vuodenajoittain. Pintavalutuskentillä ja laskeutusaltailla saavutetut poistumat laskettiin ainesvirtaamien perusteella. Kompsasuon pohjoisosan, Murtosuon ja Laakasuon pintavalutuskentillä tehtiin tutkimuksen aikana vuosittain kasvillisuuskartoitus. Pintavalutuskenttien käyttöaste määritettiin vuosina 1988 ja 1989. Kentille pidättynyttä lietemäärää mitattiin lietteenkerääjälevyjen avulla. Kompsasuon pohjoisosan pintavalutuskentältä otettiin myös turvenäytteet syyskuussa 1989. Näytteistä määritettiin orgaanisten ainesten osuus sekä ravinnepitoisuudet.

Kolmivuotisen tutkimusjakson aikana eri kohteista saatiin tietoa pintavalutuskentän toimivuudesta erilaisissa sadantaolosuhteissa. Kentille kesällä ja syksyllä kohdistunut keskimääräinen hydraulinen kuormitus oli 46—3 515 m^3 ha^{-1} d^{-1}. Kaltevuuksista ja oikovirtauksista johtuen kentät eivät olleet täysin käytössä, vaan vesi kulki tiettyjä reittejä pitkin. Vuonna 1989 pintavalutuskenttien käyttöasteet olivat Kompsasuon pohjoisosassa 60 %, Kompsasuon eteläosassa 63 %, Murtosuolla 67 % ja Laakasuolla 31 %.

Pintavalutuskentille kesällä ja syksyllä kohdistunut keskimääräinen kiintoaineskuormitus oli 0,4—12,5 kg ha^{-1} d^{-1}, ja vastaavasti orgaanisten ainesten kuormitus 3,0—62,0 kg ha^{-1} d^{-1}, kokonaisrautakuormitus 0,2—5,5 kg ha^{-1} d^{-1}, kokonaistyppikuormitus 0,2—2,8 kg ha^{-1} d^{-1} ja kokonaisfosforikuormitus 0,004—0,14 kg ha^{-1} d^{-1}. Kompsasuon pohjoiselle pintavalutuskentälle kohdistui kesä-lokakuussa yleensä pienempi keskimääräinen kiintoaine-, ravinne- sekä orgaanisten ainesten kuormitus kuin muille tutkituille pintavalutuskentille. Sen sijaan Kompsasuon pohjoisosassa oli suurin keskimääräinen nitraattityppikuormitus. Käyttöasteen mukaisen kentän pinta-alan perusteella saadaan varsinkin Laakasuolla huomattavasti suuremmat kuormitusarvot kuin kentän koko pinta-alan perusteella.

Kompsasuon pohjoiselta pintavalutuskentältä saadut tulokset osoittavat, että oikein suunnitellulla pintavalutuskentällä voidaan turvesoiden valumavesistä poistaa kiintoainesta ja myös liukoisia orgaanisia aineksia ja ravinteita. Kesän ja syksyn keskimääräinen kiintoainespoistuma Kompsasuon pohjoisella pintavalutuskentällä oli 44—74 %, ja vastaavasti orgaanisten ainesten poistuma 20—30 %, kokonaistyppipoistuma 38—74 %, ammoniumtyppipoistuma 56—95 %, nitraattityppipoistuma −10—93 %, epäorgaanisen typen kokonaispoistuma 56—95 %, kokonaisfosforipoistuma 37—68 %, ortofosfaattipoistuma 40—65 % ja kokonaisrautapoistuma 9—56 %. Pintavalutuskentillä saatiin poistetuksi kiintoainesta paremmin kuin sen yläpuolisella laskeutusaltaalla ja aiemmin tutkituilla laskeutusaltailla. Laskeutusaltaat eivät juurikaan poista valumavesistä ravinteita.

Kuivaniemen Kompsasuon eteläosan, Pudasjärven Murtosuon ja Sotkamon Laakasuon pintavalutuskentiltä saadut tulokset olivat useimmiten huonompia kuin Kompsasuon pohjoiselta pintavalutuskentältä saadut tulokset. Näiltä kentiltä huuhtoutui usein kiintoainesta, orgaanisia aineksia ja ravinteita. Näille pintavalutuskentille kohdistunut kuormitus oli useimmiten suurempi kuin Kompsasuon pohjoiselle pintavalutuskentälle kohdistunut kuormitus. Kenttien puhdistustulosta huononsivat myös oikovirtaukset sekä Murtosuon ja Laakasuon pintavalutuskentillä myös pääosin liian ohuesta turvekerroksesta johtuva valumaveden kontakti mineraalimaan kanssa.

Orgaanisia aineksia ja ravinteita poistuu turvesuon valumavedestä pintavalutuskentällä pidättyvän kiintoaineksen mukana. Pääosa epäorgaanisesta typestä poistuu kentiltä todennäköisesti denitrifikaatiolla. Merkittävin ammoniumtyppipitoisuutta pienentävä tekijä lienee nitrifikaatio. Ammonium- ja nitraattityppeä sekä ortofosfaattia voi myös pidättyä turpeeseen ja sen mikro-organismeihin. Osa valumavesien typestä, fosforista ja raudasta pidättyy kentälle humusaineksen mukana. Ravinteita pidättyy lämpimänä vuodenaikana myös pintavalutuskenttien kasvillisuuteen. Tässä tutkittujen pintavalutuskenttien kasvillisuuskartoitusten ja aiemmin tehtyjen asutuksen jätevesien puhdistustutkimusten perusteella arvioitiin, että ravinteiden poisto kentiltä kasvillisuutta korjaamalla ei ole kannattavaa.

Tutkimusten perusteella laadittiin pintavalutuskentän suunnittelu-, rakentamis- ja kunnossapito-ohjeet. Suoalueella on tehtävä monenlaisia tutkimuksia ennen pintavalutuskentän suunnitelmien laatimista ja rakentamista. Kompsasuon pohjoiselta pintavalutuskentältä saatujen kokemusten perusteella pintavalutuskentän pinta-alan tulee olla vähintään 2 % valuma-alueen pinta-alasta. Kentälle johdettavan veden tulee jakautua tasaisesti koko pintavalutuskentän alueelle. Pintavalutuskentän tulee olla mahdollisimman luonnontilainen, eikä alueella saa olla oikovirtauksia aiheuttavia vanhoja ojia. Pintavalutuskentän turvepaksuuden tulee olla yli 1,0 m, ja turvekerroksen tulee olla mahdollisimman tasapaksu ja homogeeninen. Turvelajin tulisi olla mahdollisimman vähän maatunutta rahkaturvetta. Alueella tulisi olla runsaasti kosteikkopaikkojen kasvillisuutta. Pintavalutuskentälle kohdistettavan hydraulisen kuormituksen tulisi olla alle 500 m^3 ha^{-1} d^{-1} roudattomana kautena. Tutkimuksissa määritettiin myös ohjeelliset arvot kentälle johdettavalle kiintoaines-, ravinne- ja orgaanisten ainesten kuormitukselle. Jako-ojan avulla vesi levitetään koko pintavalutuskentälle mahdollisimman tasaisesti. Vedet ohjataan pintavalutuskentältä alapuoliseen vesistöön keräilyojien avulla. Turvetuotantoalueen ulkopuoliset vedet ohjataan pintavalutuskentän ohi eristysojien avulla. Ojia kaivettaessa tulisi välttää ojien ulottamista mineraalimaakerroksiin. Pintavalutuskentän yläpuolelle tulisi rakentaa laskeutusallas. Pintavalutuskenttä ja siihen liittyvät rakenteet tehdään lopullisille paikoilleen jo ennen suon esikuivatusvaiheen ja varsinaisen kuivatusvaiheen ojitustöitä. Pintavalutuskentän yläpuolella oleva jako-oja ja laskeutusallas on puhdistettava tarvittaessa tai ainakin kerran vuodessa. Pintavalutuskenttä on pidettävä mahdollisimman luonnontilaisena. Kunnossapidon vuoksi alueelle on rakennettava hyvä kulkuyhteys.

Tutkittujen pintavalutuskenttien varsinaiset rakentamisen kustannukset muodostivat 1—5 % turvetuotantoalueiden kunnostuskustannuksista. Pintavalutuskentän rakentamiskustannukset ovat lähes saman suuruiset kuin laskeutusaltaan rakentamiskustannukset.

Jatkotutkimuksissa tulisi määrittää pintavalutusmenetelmän käyttäjälle mahdollisimman tarkat suunnittelu-, rakentamis- ja käyttöohjeet sekä määrittää menetelmän luotettavuus ja käyttöikä. Tutkimuksia tulisi jatkaa toimivilla pintavalutuskentillä sekä kunnostus- että tuotantovaiheessa olevilla turvetuotantoalueilla. Kenttien mitoitusperusteiden tarkentamiseksi tulisi selvittää keskeisimmät syyt, jotka vaikuttavat pintavalutuskenttien puhdistuskykyyn. Toimivilla pintavalutuskentillä tulisi tutkia kenttien hydrologiaa sekä kiintoaineksen ja ravinteiden pidättymiseen vaikuttavia tekijöitä. Ennen pintavalutuskenttien kovin laajamittaista käyttöä tulisi myös selvittää niiden toimivuus pitkähkön ajan (10—20 vuotta) kuluessa. Myös pintavalutuskenttien tulva-aikainen toimivuus tulisi tarkemmin selvittää. Lisäksi pintavalutuskenttien toimivuuden parantamiseksi tulisi kehittää kenttien kunnostus- ja hoitotoimenpiteitä.

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PEAT FILTRATION, FIELD DITCHES AND SEDIMENTATION BASINS FOR THE PURIFICATION OF RUNOFF WATER FROM PEAT MINING AREAS

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The aim of the present research is to develop new methods andimprove those already in use to reduce the loading of watercourses from peat mining areas. Factors examined were the use of peat filtration for the purification of runoff water, load retention by means of field ditches and improvement of the practicability and dredging of sedimentation basins. Field research was carried out in peat mining areas in the Province of Oulu in 1987–1989.

In addition to suspended matter, a peat filter also allows the removal of nutrients from the peat mining water, although its use often increases phosphorus concentrations in the water. Peat filters tend to clog very rapidly, which hampers their use, and there is as yet no satisfactory mechanical method for cleaning them.

The suspended matter content of the water issuing from a peat mining area could be reduced by means fo retention pipes, but these had no effect on nutrient concentrations.

The frequency of dredging a sedimentation basin had no significant effect on the suspended matter, nutrient and iron load caused by peat mining, and these substances even leached from the sedimentation basin as a result of dredging. Results can mainly be regarded as being characteristic of the particular study area only.

The average rate of removal of suspended matter could not be improved by means of a discharge device, i.e. a box weir, constructed at the lower end of the sedimentation basin. Sedimentation basins equipped with such a device removed suspended matter best during occasional high suspended matter loads, but had no appreciable effect on small loads. The box weir distributes the flow rates in the sedimentation basin more evenly and reduces erosion of the slopes at the discharge end. It also reduces the surface width of the basin and thus makes it easier to clean and reduces the space needed.

The findings were used to draw up instructions for the planning, constructions and management of the structuces examined.

Index words: peat production, runoff water, water pollution control, peat filtration, field ditch basin, retention pipe, sedimentation basin

1 INTRODUCTION

The use of peat for energy production has been increasing in Finland during the last few years and will continue to do so in the future. Peat mining changes both the amount and the quality of the runoff water issuing from mires, causing suspended matter, and possibly also humic substances and nutrients, to leach into lakes and rivers, particularly during periods of substantial runoff. The

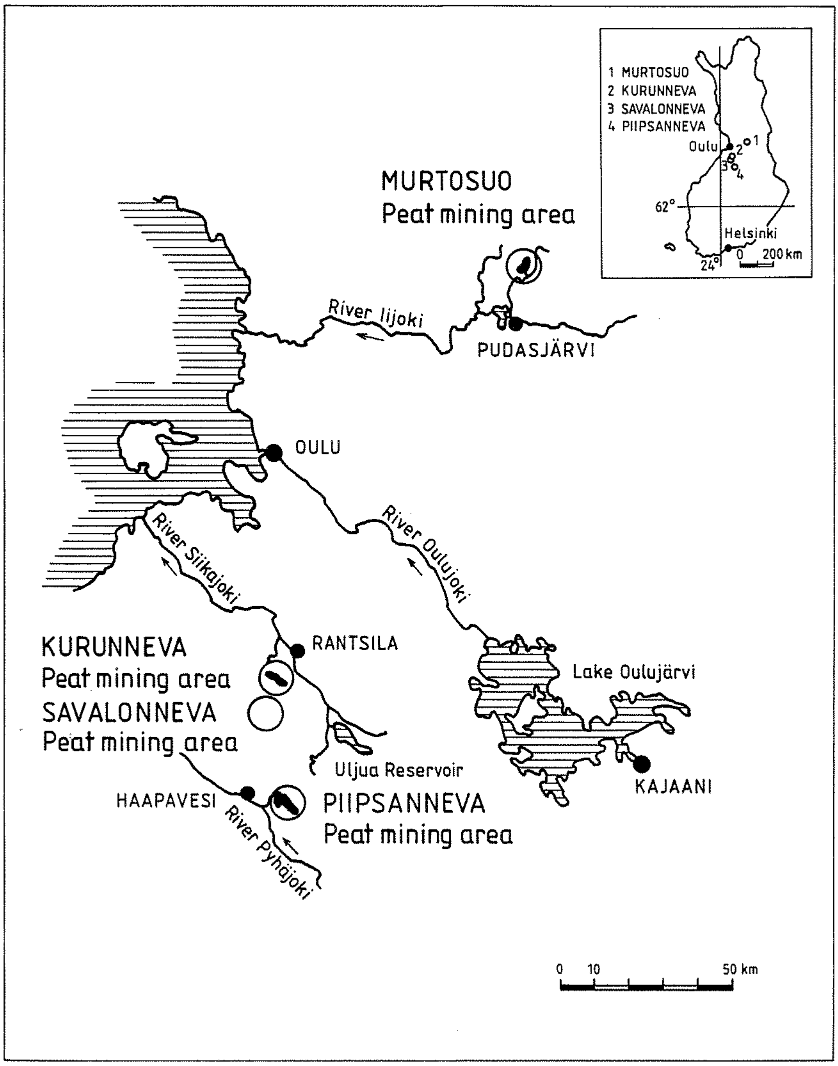

Fig. 1. Location of the sites used in the investigations, all of which are situated in the Province of Oulu.

amount of ammonium nitrogen leaching out of mires is especially marked by comparison with natural runoff, and peat mining may also constitute a significant local source of phosphorus loading.

The water issuing from peat mining areas is currently purified mainly by means of sedimentation basins, and loading further reduced by constructig the field ditches to slope as gently as possible and often providing the lower ends with field ditch basins and retention pipes. It has nevertheless proved difficult to reduce the nutrient load in particular by means of the pollution control measures currently in use.

A research project "Development of water pollution control technology in peat mining", to be carried out jointly by the Ministry of Trade and Industry, the peat producers, the water authorities, the Building Laboratory of the Technical Research Centre of Finland and the University of Oulu, was set up in spring 1987 as a result of the expansion in peat mining. The aim was to develop methods which would provide the most effective way of reducing the loading coming from mires at the various stages of preparation and mining, and to improve the methods already in use.

The effectiveness of the overland flow method was examined in the project in 1987—1989 (Ihme et al. 1991a), other methods examined being:

1. Peat filtration
2. Load retention by means of field ditches
3. Improvement of the practicability and purificavation ability of sedimentation basins

The peat mining areas investigated are situated in the Province of Oulu (Fig. 1). That of Murtosuo was at the preparation stage and Kurunneva, Savalonneva and Piipsanneva already in production.

2 PEAT FILTRATION

2.1 Background and aims of the investigation

The practicability of peat filtration for the purification of peat mining water was originally examined by Selin and Koskinen (1985). Peat was used as the active material in a box filter, field ditch filter and soil-based filter. The first type was not regarded as suitable as it was laborious to use, while the second was found to retain suspended matter effectively when maintained carefully and inspected at least once a week. Use of the soil-based filter was problematic due to its rapid clogging.

Peat filters, and particularly peat-based sludge beds, have also been used for drying the extra sludge produced by wastewater treatment plants and fish farms (Tiitto 1979, Kaunismaa et al. 1987, Selänne et al. 1983). The filters retained more than 90 % of the phosphorus, nitrogen, organic matter and solids contained in the sludge.

Investigations into the practicability of peat filtration for the purification of household wastewater, mainly carried out in the U.S.A. (Farnham and Brown 1972, Osborne 1975, Nichols and Boelter 1982, Brooks et al. 1984), indicate effective removal of suspended solids, organic matter, bacteria, phosphorus and nitrogen. The peat filtration method is best suited for the purification of small amounts of wastewater. Overseas research has also centred around the causes which affect the reductions in the concentrations of various nutrients achieved in filtration.

The aim of the present research was to examine the practicability of peat filtration for the purification of runoff water issuing from peat mining areas. The intention was to collect data on the purification capacity of peat filters and their planning, dimensioning, construction and maintenance. The main concern was their ability to remove solids from runoff water. In addition to this their practicability for the removal of soluble organic matter and nutrients was examined under conditions in which a large amount of water, maximum $1\ m^3\ m^{-2}\ h^{-1}$ is conducted through the filter, and the suspended matter content is high. The examinations were carried out using both a model of a peat filter and under practical conditions.

2.2 Study areas, material and methods

Experiments with the peat filter model (Fig. 2) were carried out at the University of Oulu in 1988 and 1989 to determine various structural alternatives for the peat filter and preliminary design and dimensioning values for a full-scale peat filter. Factors examined using the model were:

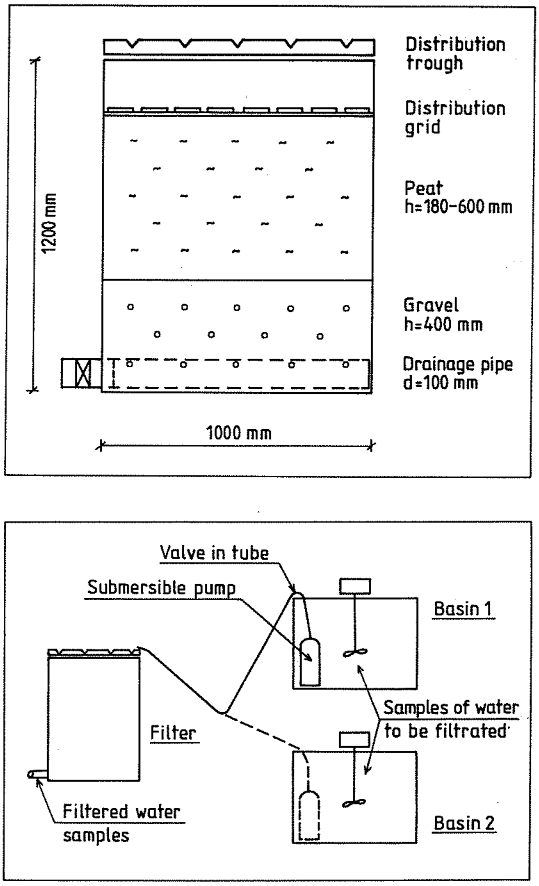

Fig. 2. Structure of the peat filter model and principle of the model tests.

- optimum peat layer thickness and surface load for the filter
- optimum grain size for subsurface drain sand
- clogging of the filter (operating life)
- effect of drying of the peat layer on the purification results
- practical solutions for the construction of a full-scale filter

Milled Sphagnum peat with a humification of H1—H3 and a peat layer thickness of 0.3—0.6 m was tested as the filter material. Experiments were also made with a 0.18 m layer of slightly humified (H1) Sphagnum peat cut in pieces of 0.15 x 0.4 m^2 by means of a disc saw during the frost period along the frost zone to a depth of approx. 0.4 m using an excavator.

Full-scale field investigations were carried out in the peat mining area of Piipsanneva in the administrative district of Haapavesi in 1988 and 1989. The total planned mining area at this site is 2 577 ha, of which 2 232 ha was ditched and 1 596 ha ready for mining. Approx. 574 000 m^3 of milled peat was lifted from the area in 1989 by Hakumethod and pneumatic harvesting method, considerable amounts of sod peat also being obtained from the area for some years. Most of the water is conducted across the area along the ditch Kotaoja into the dried up basin of Lake Likajärvi, and from there via Piipsanoja and the River Pyhäjoki into Lake Haapajärvi.

The site of investigation was established in section 14, close to the ditch Kotaoja in winter 1987—1988, three filters being constructed in the area in autumn 1988 (Fig. 3 and 4). The filters were established in a layer of natural gravel spread over the area in the preceding winter. The width of the filter basin was 4.0 m, length 10.0 m, height 1.2 m and gradient of filter basin slopes approx. 1:1, i.e. the total filter area was around 80 m^2. The basin was provided with a waterproof lining which was covered by levelled crushed gravel, with five subsurface drains constructed above these and

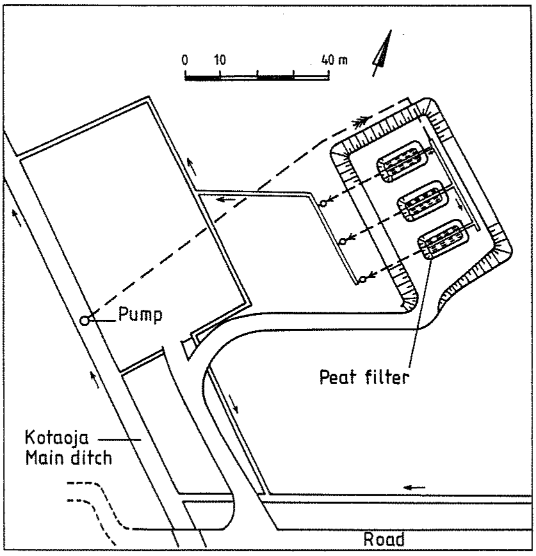

Fig. 3. Site of the peat filter tests in the peat mining area of Piipsanneva.

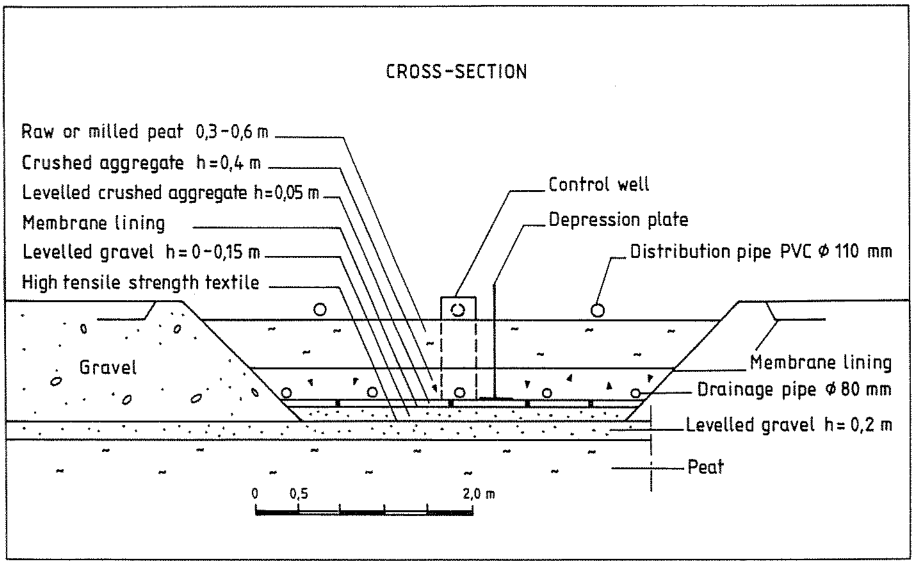

Fig. 4. Cross-section of the peat filter at Piipsanneva.

connected to a discharge pipe and a flush pipe. The subsurface drains were overlain by a 0.4 m layer of crushed gravel which was further covered by filter peat. Water pumped from the main outlet ditch in Piipsanneva was conducted through the filter and distributed over the peat layer by means of plastic pipes.

The filtration tests were started on 23.5.1989, a total of eight tests being carried out in summer 1989. Milled peat was used as the filter material in six cases and pieces of raw peat in two cases, both peat types being similar to those tested using the model. Surface loads of 0.25 m h^{-1}, 0.50 m h^{-1} and 1.00 m h^{-1} were used in milled peat filtrations in which the peat thickness was 0.3 m and 0.6 m. In the case of raw peat filtration the peat thickness was 0.4 m and the surface load 0.5 m h^{-1} and 1.00 m h^{-1}. Samples of the water conducted to the peat filter were taken from the water distributor well located at the end of the filter basins. The filtered water samples were obtained from the discharge pipe and analyses for solid matter, chemical oxygen demand (COD_{Mn}), total N, NO_3—N, NH_4—N, total P, PO_4—P and total Fe content using methods generally employed by the Finnish environmental authorities (National Board of Waters 1981).

2.3 Results and discussion

The most significant results obtained in the peat filtration tests are discussed and presented here, a more detailed report being provided by Ihme et al. (1991b).

The average loads imposed on the peat filter of Piipsanneva during the various tests are presented in Table 2. The load values were calculated for a period longer than that used for the actual filtration test and are based on the average surface loads (0.61 m h^{-1}) and the mean concentrations observed in the peat mining water during the tests in summer. Thus the load values can be taken to represent a situation in which the filters were continuously in operation.

In cases where peat filtration has been used for houdehold wastewater purification, the mean surface load was 0.8 x 10^{-3} m h^{-1} while the figures recorded for Piipsanneva varied from 0.25 to 1.00 m h^{-1} (Table 1). Due to the large amount of water, the mean suspended matter load imposed on the peat filter at Piipsanneva was on average 320 times higher than the corresponding values obtained for household wastewater (Nichols and Boelter 1982, Brooks et al. 1984, Rock et al. 1984), that of organic matter 80 times higher, total N

Table 1. Full scale peat filtration tests conducted at the peat mining area of Piipsanneva in 1989.

Test	Duration time	Peat type	Surface load m h^{-1}	Peat thickness m	Filtration periods
A[1]	23.—30.5.1989	Milled	0.25	0.6	6 separate
B[1]	17.—30.5.1989	Milled	0.50	0.3	4 separate
C[2]	26.—29.6.1989	Milled	0.50	0.6	1 continuous
D[2]	6.—22.6.1989	Milled	0.50	0.3	6 separate
E[2]	6.—22.6.1989	Milled	1.00	0.3	6 separate
F[3]	26.7.— 8.8.1989	Raw	0.50	0.4	1 continuous
G[3]	7.—12.8.1989	Raw	1.00	0.4	2 separate
H[3]	18.—30.8.1989	Milled	0.50	0.6	3 separate

[1] Peat placed in October 1988, [2] Peat placed in June 1989, [3] Peat placed in July 1989

Table 2. Average load imposed on the peat filter at Piipsanneva during various filtration tests. See duration times, peat types and peat thicknesses in the Table 1.

Test	Surface load m h^{-1}	Average load (g m^{-2} h^{-1})							
		SS	COD_{Mn}	Tot.N	NH_4—N	NO_3—N	Tot. P	PO_4—P	Tot.Fe
A	0.25	3	10	0.6	0.3	0.03	0.02	0.01	0.7
B	0.50	8	20	1.2	0.5	0.06	0.03	0.01	1.4
C	0.50	46	43	2.4	0.8	0.06	0.06	0.01	2.6
D	0.50	46	43	2.6	0.8	0.09	0.06	0.01	2.2
E	1.00	168	91	4.7	1.6	0.18	0.12	0.03	4.3
F	0.50	25	37	2.8	1.4	0.09	0.07	0.02	1.9
G	1.00	64	74	5.4	2.5	0.20	0.12	0.04	5.7

SS = suspended solids

load 80 times, NH_4—N load 60 times, NO_3—N load 25 times and total P 9 times higher (Table 2). As the flow velocities in the Piipsanneva filter were fairly high by comparison with the loads presented earlier, the filtration process can be regarded as being mainly a mechanical one.

Milled peat and pieces of raw peat were found to be equally effectice for filtering suspended matter from runoff water (Table 3). In this respect peat filtration seems also to be more efficient than sedimentation basins, reductions of 30—40 % been achieved by the latter (Selin and Koskinen 1985). The mean reduction for suspended matter was lower than that observed in the peat filtration tests on household wastewater, reductions of 90—94 % having been achieved by the latter (Brooks et al. 1984, Rock et al. 1984).

The mean organic matter reductions in the raw peat filtration tests were almost equal to the highest reduction values obtained in the milled peat filtration tests (Table 3) and lower than in peat filtration tests for household wastewater, where the figure have been over 80 % (Brooks et al. 1984, Rock et al. 1984).

The mean total N reductions observed in the milled peat filtrations were slightly higher than those obtained in the raw peat filtrations (Table 3). These reductions were lower than those obtained for household wastewater, which were approx. 50—90 % (Nichols and Boelter 1982, Brooks et al. 1984, Rock et al. 1984).

Apart from filtration test A, the mean total reductions of inorganic nitrogen and the reduction of NH_4—N in the milled peat filtrations were higher than those recorded in the raw peat filtrations (Table 3). Nitrate nitrogen was found to leach out of peat both in milled and raw peat filtrations. It has been possible to remove 69—83 % of the NH_4—N contained in household wastewater by means of peat filtration (Brook et al. 1984), whereas the NO_3–N content has remained constant or increased slightly.

The reductions in total P achieved in the raw peat filtration tests were higher than those observed in the milled peat tests (Table 3), as the amount of PO_4—P leaching out of the raw peat was markedly lower. The mean reductions in total P in the raw peat filtrations were lower than those obtained when applying peat filtration to household wastewater purification, for which the reductions varied between 10 % and 96 % (Nichols and Boelter 1982, Brooks et al. 1984, Rock et al. 1984). Contrary to those obtained for peat mining water, the total P concentrations for household wastewater were so high that the possible leaching of phosphorus out of the peat could not have had any appreciable effect on the purification results.

The reductions in total Fe achieved in the milled peat filtration tests were markedly higher than those obtained in the raw peat filtrations tests (Table 3), probably due mainly to the fact that milled peat has a higher humification than raw peat, thus containing more ironbinding humic substances. Household wastewater is usually characterized by low Fe concentrations, and thus no attention has been paid to the retention of Fe in its purification.

Organic matter, nutrients and Fe are removed from the peat mining water by the suspended matter retained in the peat. Inorganic N is probably removed from the filter by denitrification, which has often proved to be the main agent for this in the purification of household wastewater (Jaouich 1975, Rock et al. 1984). Ammonium nitrogen may be retained in peat chemically (Burge and Broadbent 1961, Lance 1972, Clymo 1983), in addition to which both it and NO_3—N may be retained under aerobic conditions in microbes found in the peat surface (Lance 1972). The main cause of the reduction in NH_4—N concentrations

Table 3. Average reductions observed in milled peat and raw peat filtration tests in the Piipsanneva peat mining area in summer 1989. See duration times in the Table 1.

Test	Peat type	Peat thickness m	Surface load m h^{-1}	Average reduction %								
				SS	COD_{Mn}	Tot. N	NH_4—N	NO_3—N	Inorganic N	Tot. P	PO_4—P	Tot. Fe
A	Milled	0.6	0.25	39	−56	−13	−4	14	−2	−152	−362	53
B	Milled	0.3	0.50	34	−26	12	35	−1	31	−86	−266	40
C	Milled	0.6	0.50	63	4	23	31	0	29	−60	−380	31
D	Milled	0.3	0.50	75	27	28	8	−4	7	−37	−215	55
E	Milled	0.3	1.00	79	21	21	14	−7	12	−81	−390	51
F	Raw	0.4	0.50	56	9	8	2	−45	0	11	−9	8
G	Raw	0.4	1.00	72	18	12	1	−7	1	9	−28	23

in the filter may be nitrification. Orthophosphate is retained in peat microbes under aerobic conditions (Kaila 1956, Karimo 1966, Farnham and Brown 1972, Rock et al. 1984), or by ion exchange reactions, its chemical retention being intensified with increased aluminium, iron and calcium in the peat (Farnham and Brown 1972). Iron-rich humic substances also tend to be retained easily (Thurman 1985), so that iron is also retained in the peat by virtue of these substances.

The purification results achieved by peat filtration are also affected by the leaching of organic matter and nutrients out of the peat, particularly in the purification of runoff water from peat mining areas, which has lower concentrations of suspended and dissolved substances than does household wastewater. Suspended matter leached out of the peat at the beginning of the filtration tests in particular, and "soluble" organic substances were also occasionally found to do so. The leaching of suspended matter and organic matter was most pronounced in the milled peat filters into which the peat had been placed in the autumn preceding the summer during which the filtration tests were conducted. The main reason for this may be the influence of the weather in winter and spring. The suspended matter and organic matter leaching out of the peat increased the total N, total P and total Fe concentrations in the filtered water. Ammonium nitrogen leached out of the milled and raw peat occasionally, possibly being released as a result of a decomposition process or an occasional oxygen deficit in the subsurface peat layers. Orthophosphate leached out of the peat in all the milled peat filtration tests, while this was considerably more rare in the raw peat filtration tests. This may be due to the fact that there was a smaller amount of P in the raw peat originally, and that the raw peat was not as well decomposed as the milled peat. The leaching of PO_4—P may also have been increased by the occasional oxygen deficit in the subsurface peat layers. There was some leaching of Fe in the course of the longest raw peat filtration test, possibly explained by the occasional oxygen deficit in the lowermost peat and sand layers in the filter.

The field tests carried out in Piipsanneva indicated that the major problem for the purification of peat mining water by means of peat filtration is the fairly rapid clogging of the filter. The longest continuous milled peat filtration before the filter became clogged was approx. 3 days. The filter had a peat layer with a thickness of 0.6 m and the surface load of 0.5 m h^{-1}. The amount of water conducted through the filter was 2 700 m^3 and that of suspended matter 1.6 kg m^{-2}. The longest period of continuous raw peat filtration before clogging was approx. 13 days, by which time 11 800 m^3 of water and 7.8 kg m^{-2} of suspended matter been conducted into it. The thickness of the peat layer was 0.4 m and the surface load 0.50 m h^{-1}. The results indicate a maximum continuous operation time of 3.5 days for an 80 m^2 milled peat filter in a peat mining area with a catchment area of 100 ha, given an average runoff of 10 l s^{-1} km^{-2} and an average suspended matter concentration of 40 mg l^{-1} in the runoff water. The corresponding maximum continuous operating time for a raw peat filter is 18 days, the higher value being explained by the fact that some of the suspended matter was retained in the deeper peat layers.

Provided that the costs can be covered, peat filtration may be used for the purification of runoff water from peat mining areas of reduced depth, for example, which are being dried by pumping. The method is best suited for the treatment of runoff water during the warm season, when total runoff is low.

2.4 Construction and dimensioning of a peat filter

Coarse-grained Sphagnum raw peat of low humification was considered a better filter material than milled peat. The thickness of the raw peat layer must be at least 0.4 m, and the filter layer should be constructed to be as dense as possible and of as large pieces of peat as possible to prevent the water from flowing through the joints between the peat pieces.

The maximum surface load should be 0.5—1.0 m h^{-1}. The raw peat filter became clogged at a suspended matter load of 7.8 kg m^{-2}, which may thus be regarded as the maximum value for this kind of filter. A total of 11 800 m^3 of water was conducted through the filter at a surface load of 0.50 m h^{-1}, the entire filtration process lasting about two weeks. The peat layer must have an underlay of 0.4 m crushed aggregate of grain size 5—12 mm, the finest material in which has been washed out. Subsurface drains must be installed under the gravel layer and their ends connected to discharge pipes and flush pipes.

An allowance of 0.5 m should be left in the upper part of the filter basin. Water must be conducted through the filter continuously to prevent it from drying and must be distributed evenly over the filter surface by means of plastic pipes and distribution wells, for example. A sedimentation basin must be built in connection with the pumping station to reduce the suspended matter load imposed on the filter.

The peat filter should be constructed on mineral soil of adequate bearing capacity, and its use requires the availability of electricity in the area. This is because the runoff water must almost invariably be conducted to the filter by pumping.

3 LOAD RETENTION IN FIELD DITCHES

3.1 Background and aim of the investigation

A dense field ditch network is constructed in peat mining areas (500 m ha^{-1}), and these ditches may also be used as sedimentation basins. As the catchment area of one ditch is small, the maximum amount of water is also restricted and flow conditions remain stable.

The lower end of the field ditch is always provided with pipe drains, to act as drums when the excavators are moved from one production field of peatland to another. Various retainers can be attached to the ends of the pipe drains closest to the field ditch to keep the pipe drains open and improve the suspended matter retention capacity of the ditches. In addition, small field ditch basins, i.e. sludge pockets, can be constructed at the lower ends of the field ditches.

The aim of the present research is to examine the practicability of the various retainer alternatives for water pollution control, and to determine the role of field ditch basins, retainers and a combination of these in the reduction of suspended matter loads.

3.2 Sites

3.2.1 Piipsanneva

The retention pipe tests were carried out in sections 2 and 3 of the Piipsanneva peat mining area in the administrative district of Haapavesi in 1987 and 1988 (Fig. 5). The peat mining area is described in more detail in Section 2.2.

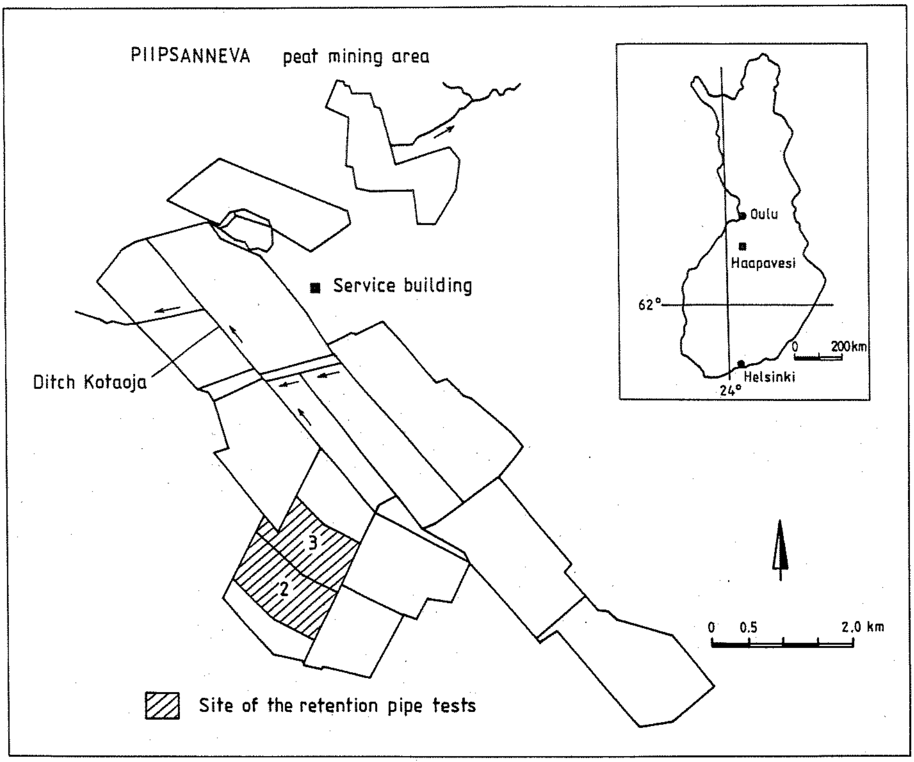

Fig. 5. Sites used for retention pipe tests at Piipsanneva.

The practicability of the various retainers was examined in an area where the field ditches extend down to the mineral soil and one in which ditches had been entirely dug into peat. In addition, the practicability of ditches with no retainers was assessed. The field ditches were 640 m in length and fields 20 m in width, i.e. each ditch had a catchment area of 1.28 ha.

The retainers used consisted of various plastic, metal and subsurface retention pipes and metal plates with holes (Table 4, Figs. 6 and 7). Each retainer type was tested for its practicability in two ditches in each section, field ditch basins been constructed in front of the retainers.

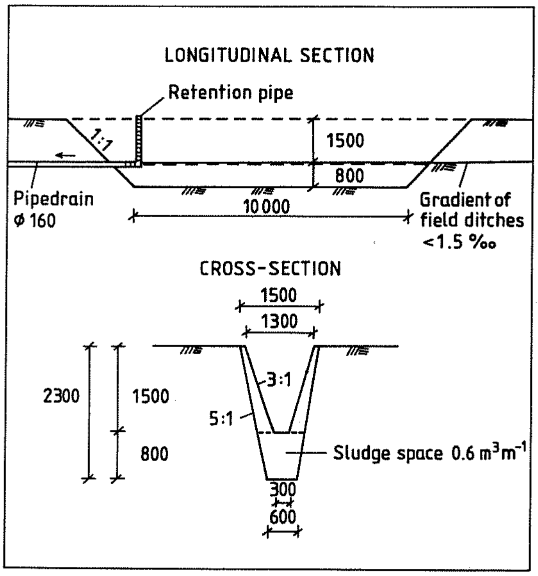

Fig. 6. Longitudinal and cross-sectional drawings of the basin at the lower end of the field ditch and the related pipe drain and retainer constructions.

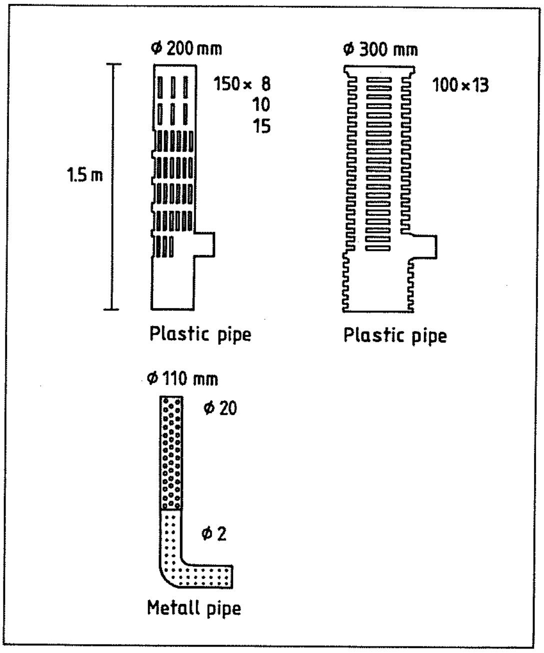

Fig. 7. Retention pipes examined at Piipsanneva in 1987 and 1988.

Table 4. The retainer types attached to the end of pipe drain tested in the Piipsanneva and Savalonneva peat production areas.

Retainer type	Diameter mm	Slots mm x mm	Water quality monitoring		
			Piipsanneva		Savalonneva
			1987	1988	1989
Plastic pipe	300	Horizontal 100 x 13	x	x	x
Plastic pipe	140	Vertical 150 x 15			
Plastic pipe, surrounded with steel net	140	Vertical 150 x 10	x	x	
Plastic pipe	200	Vertical 150 x 8			
Plastic pipe	200	Vertical 150 x 10	x		
Plastic pipe	200	Vertical 150 x 15			
Metallic pipe	110	Round Ø20			
Metallic pipe	110	Round Ø20, in the bend Ø2	x		
Plastic subsurface drain pipe	Horizontal pipe	Slot area 50 cm^2/pipe m			
Metallic plate	Shaped to cross-section of ditch			x	

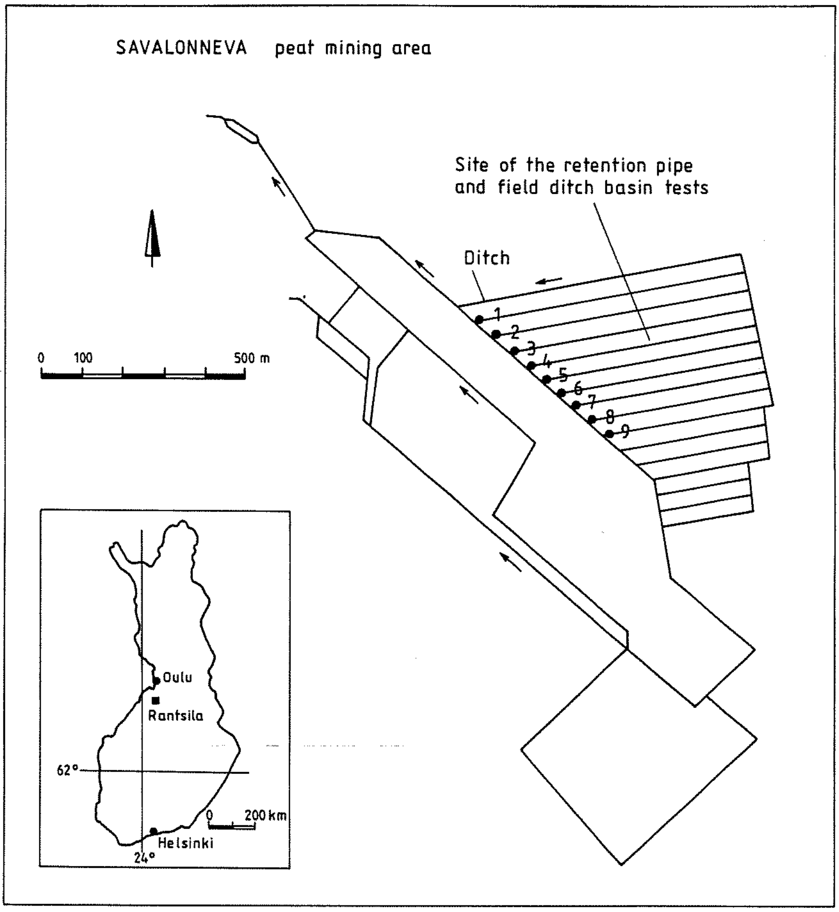

Fig. 8. Site used for retention pipe and field ditch basin investigations at Savalonneva.

3.2.2 Savalonneva

Retention pipe and field ditch basin tests were also carried out in section 8 of the Savalonneva peat mining area located in the administrative district of Rantsila in 1989 (Fig. 8). The section has a mining area of 26 ha of Sphagnum-Carex peat of thickness 2.4 m and humification H 5.0. The water issuing from the surrounding region is conducted outside the peat mining area. Savalonneva was prepared for peat mining in 1987—1989, and the first milled peat was lifted in 1989, a total of 12 000 m^3.

The role of a field ditch basin, a retainer and a combination of these in the retention of suspended matter was examined here. The field ditches, 400—700 m in length, were dug into peat. The width of each field was 40 m and a subsurface drain was constructed in the middle of each. Three structural alternatives for the lower end of the field ditch were examined:

a. Ditch with neither a field ditch basin nor a retainer,
b. Ditch with a field ditch basin but no retainer,
c. Ditch with a field ditch basin and a retainer.

Field ditches 1, 4 and 7 were of type a, ditches 2, 5, and 8 of type b, and ditches 3, 6 and 9 of type c (Fig. 8). A plastic pipe retainer of diameter 300 mm was used as the retainer (Table 4) and a plastic pipe drain of diameter 160 mm was installed in each ditch.

3.3 Material and methods

The practicability of the various field ditch constructions was monitored on the basis of water samples, flow measurements and visual observations. Daily rainfall values were supplied by the Meteorological Station at Haapavesi. Flow rates were measured weekly in all the field ditches examined below the pipe drain by a container method, water samples also being obtained from above the field ditch basin and below the pipe drain. Samples were also taken from ditches with no retainers at Piipsanneva and analysed for suspended matter content, chemical oxygen demand (COD_{Mn}), total N, total P and total Fe content by methods generally employed by the Finnish water authorities (National Board of Waters 1981). The samples taken from Savalonneva were also examined for suspended matter content and chemical oxygen demand (COD_{Mn}).

The suspended matter load imposed on the field ditches was calculated from the transport rates and concentrations observed at the time when the samples were taken. The average reductions in suspended matter achieved by means of the various field ditch constructions and the reductions in organic matter obtained at Savalonneva were calculated from the transport rates. Average reductions in total nutrients and total Fe were calculated only from the concentrations in the samples taken from Piipsanneva in 1987.

The practicability of the field ditch constructions was monitored by keeping a field diary of all factors affecting water quality and drainage of the peat mining area, together with the various maintenance requirements, problems and other factors related to the practicability of the constructions.

3.4 Results and discussion

The most important results obtained regarding load retention in the fied ditches are discussed in this section. Further details will be presented and discussed in a more extensive report (Ihme et al. 1991c).

3.4.1 Water permeability of various retainers

Total rainfall during June—August was generally higher than the long-term averages, and there were occasional downpours in the areas, but also periods that were drier than average. Data were thus obtained on the practicability of the field ditch structures at the various sites under different rainfall conditions.

The investigations carried out at Piipsanneva indicated that a 300 mm plastic pipe retainer with 100 x 13 mm^2 horizontal slots, and a 200 mm plastic pipe retainer with 150 x 15 mm^2 vertical slots have the highest water permeability both in field ditches excavated in mineral soil and those constructed in peat. Their water permeability was nearly as high as that of field ditches with no retainer. The lowest flow dispersion was observed in ditches with a 300 mm plastic pipe retainer, which suggests that the retainer does not became clogged easily, whereas the ditches without a retainer used for comparison became clogged from time to time. The retainers of smallest diameter, constructed of plastic pipes, metal pipes, subsurface drainpipes or metal plates, had the poorest permeability values. After rain, the watertable remained higher in the ditches provided with a metal plate than in the other ditches observed. The amount of water entering the field ditches was affected by environmental conditions, which hindered comparison of the retainers.

It was not possible to provide a detailed account of the water permeability of the various field ditch constructions in Savalonneva, either. The highest flows were observed in field ditches located in the middle of the site, representing three ditch types to be examined. As the ditches were of different lengths and located at intervals of 40 m with a subsurface drain constructed in between, the water was distributed to them unevenly.

3.4.2 Water quality and suspended matter load in field ditches

Suspended matter content of water in the field ditches of Piipsanneva was 1.2—2 530 mg l^{-1}, COD_{Mn} 14.5—2 830 mg l^{-1}, total N content 1.3—20.5 mg l^{-1}, total P content 1—230 μg l^{-1} and total Fe content 0.6—22.4 mg l^{-1}. The suspended matter content of the water leaching into the field ditches of Savalonneva was 1.8—193 mg l^{-1} and its COD_{Mn} 22.1—169 mg l^{-1}. The average water quality was more or less similar to that for the peat mining areas examined earlier. The suspended matter concentrations were highest after periods of intense rain and during cleaning of the field ditches.

There were considerable variations in the suspended matter load imposed on the field ditches of Piipsanneva, where the average value was 0.04—8.86 kg d^{-1}, while the load at Savalonneva was lower, i.e. 0.06—0.52 kg d^{-1}. Suspended matter load is mainly affected by hydraulic load and the concentrations of the various substances in the runoff water, considerable variation being observed in the field ditches in this respect.

3.4.3 Purification results

It is possible to remove suspended matter from the runoff water issuing from peat mining areas by means of retention pipes and field ditch basins (Table 5 and 6). The various field ditch constructions did not have any significant effect on the nutrient concentrations observed.

A field ditch with a 300 mm plastic pipe retainer removed suspended matter most effectively, i.e. 78—97 % (Table 5), and evenly, which means that the concentrations observed in the outgoing water were almost invariably lower than in the incoming water. When the suspended matter content was over 20 mg l^{-1}, it was also possible to remove suspended matter by means of a metal plate and a 140/10 mm plastic pipe retainer surrounded by a steel mesh. Suspended matter was occasionally found to leach out of field ditches provided with such constructions, particularly in the case of small-diameter plastic pipe retainers in 1987. Suspended matter was also removed from the ditch with no retainer when the concentrations exceeded 20 mg l^{-1}. The retainers removed suspended matter almost equally efficiently in the ditches constructed in mineral soil and those constructed in peatland.

The high suspended matter concentrations occurring during periods of intense rain and the cleaning of field ditches were reduced markedly by the retention pipes and field ditch basins. The best results, particularly with high suspended matter concentrations (reduction 78—97 %) were obtained using a 300 mm plastic pipe retainer (Fig. 9).

Field ditches provided with retention pipes do not become clogged as rapidly as those with no retainer, i.e. markedly high suspended matter concentrations were occasionally observed in the reference ditch (with not retainer). The retention pipe became clogged from time to time, and when it was cleaned, a considerable amount of suspended matter leached out of it and the field ditch basin into the downstream collection ditch.

The field ditches which removed suspended matter often removed organic substances, nutrients and iron, at the same time, even though these substances were also found to be leached into the water from time to time.

At Savalonneva 3—78 % of the suspended matter was removed by means of the various field ditch constructions available (Table 6). When comparing the practicability of the three field ditch types constructed in the middle of the site (ditches 4, 5 and 6), the highest reduction in suspended matter was obtained by means of the field ditch containing a basin and a retainer. Suspended matter was removed most successfully at high concentrations, but also when these were low, even less than 10 mg l^{-1} (Fig. 10). Suspended matter was also retained in a field ditch containing only a field ditch basin, particularly at high loads. The ditch with neither a field ditch basin nor a retainer

Table 5. Average reductions observed in field ditches provided with different types of retention pipes in sections 2 and 3 at the Piipsanneva peat mining area in 1987—1988. Field ditch basin was constructed in each ditch.

Site/ Retainer type	Average reduction %						
	1987					1988	
	SS[5)]	COD_{Mn}[6)]	Tot.N[6)]	Tot.P[6)]	Tot.Fe[6)]	SS[5)]	COD_{Mn}[5)]
Section 2							
Plastic 140/10[1)]	46	3	0	5	11		
Plastic 140/10 + N[2)]						48	26
Plastic 200/10	− 4	2	−14	−1	− 4		
Plastic 300	89	37	19	16	15	97	52
Metallic 110/20 and 2[3)]	40	25	2	6	10		
Metallic plate						12	3
Reference ditch[4)]	49	13	7	14	−16	43	−1
Section 3							
Plastic 140/10	−98	−8	− 6	6	1		
Plastic 140/10 + N						85	54
Plastic 200/10	−30	12	− 2	−2	15		
Plastic 300		35	4	8		78	40
Metallic plate						94	85
Reference dithc						89	62

1) Diameter 140 mm, width of the vertical hole 10 mm, 2) Surrounded with steel net, 3) Diameter 110 mm, slot diameter 20 mm and 2 mm, 4) Field ditch without retainer, 5) Estimated with transport rates, 6) Estimated with concentrations
SS = suspended solids

Table 6. Average reductions in suspended matter and organic matter in fild ditches at the Savalonneva peat mining area in 1989.

Field ditch	Type[1)]	Average reduction %	
		Suspended matter	COD_{Mn}
1	a	64	14
2	b		
3	c	3	−1
4	a	21	2
5	b	25	6
6	c	55	6
7	a	26	0
8	b	33	1
9	c	78	8

[1)] a = field ditch without basin and retainer pipe
b = field ditch with basin and without retainer pipe
c = field ditch with basin and retainer pipe

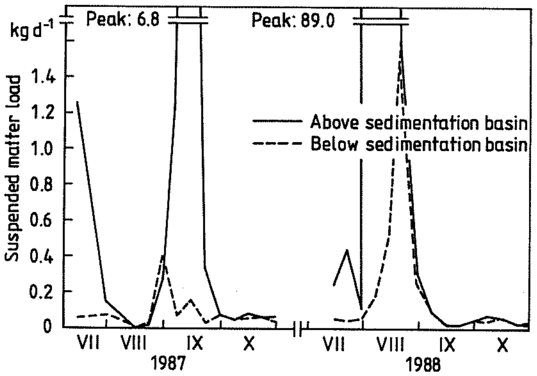

Fig. 9. Suspended matter load in a field ditch equipped with a 300 mm plastic retention pipe in section 2 at Piipsanneva in 1987—1989.

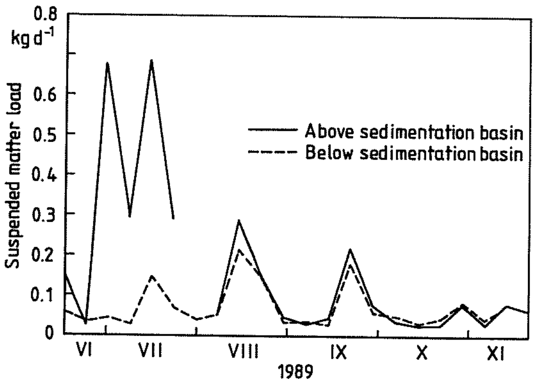

Fig. 10. Suspended matter load observed in field ditch 6 at Savalonneva, equipped with a field ditch basin and a retainer (type c).

became clogged easily, and no samples could be obtained.

One problem affecting the comparison of the retention pipes and field ditch constructions in terms of practicability was the considerable variation in the quality and amount of water leaching into the various field ditch basins, even though they were located in the same area. The samples were taken only once a week and the load peaks did not always occur at that time. All these factors hampered the evaluation of the purification results.

3.5 Planning, construction, maintenance and costs of field ditches, field ditch basins and retainers

3.5.1 Investigations and dimensioning

The field ditch investigations and field surveys necessary for the structures required in the ditches (basins, retainers) should be carried out in connection with research for other ditching work, to determine locations for the field ditches and the constructions to be placed in these, to collect data on soil and hydrology, and to provide the necessary longitudinal and cross-sectional measurements.

The longitudinal gradient of the field ditches should be less than 1.5 ‰ and slope as gently as possible towards the end of the pipe drain. Sludge retention can be improved throughout the ditch network by means of sludge pits.

A dimensioning value of 300 l s^{-1} km^{-2} can be used for the field ditch basin when no sedimentation basins proper are constructed in the area (Selin and Koskinen 1985). The field ditch basin should not be much wider than the field ditch itself, otherwise it will impede the use of machines, as these may cause the slopes to cave in as they pass over. In addition the machines may deposit peat dust in the basins if these are too wide. Field ditch basins should be long enough to achieve the recommended dimensioning values, and usually require more sludge space than actual sedimentation basins, which have a sludge dimensioning value of 4 m^3 ha^{-1}. The depth of a field ditch basin is affected by factors such as soil type and purification equipment. The longitudinal and cross-sectional measurements obtained for a field ditch basin are presented in Fig. 6.

A 110—160 mm plastic pipe is used as a pipe drain at the lower end of the field ditch. Should no actual retainer be used, the minimum diameter of the pipe drain should be 140 mm.

The retainer constructed in front of the pipe drain should:

- prevent lumps of peat from entering it
- cause water to accumulate in the field ditch during periods of intense rain and not in the peat mining area
- allow rapid, easy cleaning
- withstand cleaning work and frost, for example
- entail low costs, as the number of retainers required is high.

Of the retainers examined here, a 300 mm plastic pipe retainer with 100 x 13 mm^2 horizontal slots was found to function best in terms of both the retention of suspended matter, drainage of the peat mining area and endurance. The cleaning of suspended matter from the plastic pipe retainer was also easier than from a metal one.

3.5.2 Construction and maintenance

The field ditches and related constructions should be established in connection with the preliminary drainage work, and the field ditch basins and retainers should be constructed before the field ditch. The retainer should be installed low enough that it does not prevent mechanical cleaning of the field ditches or the moving of wide vehicles from one field to another.

The field ditches and the basins constructed in these should be cleaned when necessary, and at least once a year. This should be done at the end of the peat mining season, before autumn rains and after the periods of exceptionally intense rain in summer. The field ditch basins usually have to be cleaned more frequently than the actual sedimentation basins.

The pipe drains must be stopped up for the cleaning period, to prevent the peat sludge from being transported downstream to the lakes and rivers. The field ditches and basins should be cleaned in such a way as to prevent the slopes from caving in or any damage occurring to the retainer structures.

Should the ditches or basins extend down to the mineral soil, the sludge from any ditch or field ditch basins should be transported out of the peat mining area, for if spread over the area, this mineral soil will increase the ash content of the peat, which will thus become more difficult to use. In addition, the sludge removed from a ditch is usually highly fluid and can easily flow back into the same ditch or the adjacent one.

The retainers fitted to the field ditches should be serviced regularly. They should be cleaned (brushed, beaten) at the same time as the field ditch basins, or even more frequently if necessary. The cleaning work should be done with care to prevent the peat sludge from being transported to the lakes and rivers downstream and causing damage to the retainers.

Field ditches and field ditch basins can be cleaned using a number of devices operating on different principles. The end of the field ditch closest to the pipe drain should always be cleaned first.

3.5.3 Costs

The costs arising from the use of retainers in field ditch basins are 85—150 FIM per hectare of peat mining area (1989 prince level), given fields of length 1 000 m and width 20 m. Additional costs arise from the installation of retainers, servicing and maintenance. The construction costs suggested for a field ditch basin are 90 FIM ha^{-1}, again at the 1989 price level (Selin and Koskinen 1985), while the corresponding costs for a field ditch basin with retainer would be 175—240 FIM ha^{-1}. The above costs are usually lower than those arising from the construction of a sedimentation basin, which are 470—920 FIM ha^{-1} (Selin and Koskinen 1985).

3.6 Need for further investigations

Further investigations should be geared towards providing the user of field ditch basins and retainers with as exact planning, construction and operating instructions as possible. The functioning of different retainers should be further examined under controlled conditions and attention should be paid to the peat mining and maintenance measures employed in the area. Possible combinations of water processing methods should also be looked at in the future.

4 IMPROVING THE PRACTICABILITY OF SEDIMENTATION BASINS

4.1 Background and aim of the investigation

Sedimentation basins constitute the most common method used for purifying runoff water from peat mining areas. As indicated by investigations carried out earlier, improvements need to be made in the structure of sedimentation basins and their practicability (Selin and Koskinen 1985).

The aim of this investigation was to develop the structures used in sedimentation basins in such a way as to improve their practicability, structural endurance and maintenance properties. The effect of dredging frequency on the purification results and the applicability of a box weir installed at the lower end of the basin was examined at the various sites.

4.2 Sites

4.2.1 Kurunneva

The effect of dredging frequency on the purification results was examined in the peat mining area of Kurunneva in the administrative district of Rantsila (Fig. 11). The peatland concerned was drained in 1956 and ditched in 1976 for the peat production. Peat mining started in the area in 1977, and a total of 346 ha had been used for this purpose by 1987. The main type obtained from the area is milled peat, which was chiefly composed of Carex or Sphagnum peat when mining began, with a humification of H 4.7 and mean depth of 1.6 m. The bottom of the mire is composed of silty till, and the water issuing from the mire is conducted through sedimentation basins and via the Kurunkanava channel and the brook of Savaloja into the River Siikajoki. Some of the water also comes from some 84 ha of land lying outside the peat mining area, i.e. the total drainage basin is 343 ha, of which runoff water not connected with peat mining constitutes approx. 26 %. The collection ditches extend down to the mineral soil in some places.

The tests were carried out on sedimentation basins of length 130 m, width 14 m and total depth 3.3 m located in the peat mining area south of Kurunkanava (Figs. 11 and 12). The basins contain surface booms to prevent floating matter from being transported into the lakes and rivers downstream. Triangular Thompson's measuring weirs were established in a drum structure in the lower parts of the sedimentation basins, which were dredged using a suction dredger developed by Vapo Oy and the Lännen company (Sänkiaho 1990).

4.2.2 Murtosuo

The practicability of the dam structure at the discharge end of the sedimentation basin was examined in the peat mining area of Murtosuo in the administrative district of Pudasjärvi (Fig. 1). The planned mining area of 129 ha is divided into three sections (Fig. 13) and is dominated by Carex peat with a mean humification of H 5.0 and mean depth of 2.1 m. A total of 3.2 million m^3 of natural peat is available in the area, which will mainly be lifted in the form of milled peat.

The investigations were carried out in section 2, with an area of 60 ha (Fig. 13), the construction of which began in autumn 1987. The water issuing from this section is conducted through double sedimentation basins into the River Kivarinjoki, from which it runs via Lake Kivarinjärvi and the River Törröjoki to the River Iijoki (Fig. 13). The basins, constructed in November 1987, are of length 63 m, width 12 m and total depth 3 m (Figs. 13 and 14).

Box weirs developed by the Water and Environment District of Kainuu were installed at the discharge ends of the two basins in November 1987 (Fig. 15), one equipped with triangular Thompson's measuring weirs and another with boards provided with holes. The watertable is at the level of the holes at times of low runoff. Set planks are used to block the passage of water at runoffs of 100—300 l s^{-1} km^{-2}, which increases the pressure and flow of the water through the bottom holes. The cross-sectional area of the sedimentation basin increases with damming, i.e. the flow rate will be approx. 0.01 m s^{-1} irrespective of that of the incoming water. The water also discharges above the uppermost set plank in the box weir at a flow rate of over 300 l s^{-1} km^{-2}.

4.3 Material and methods

The tests were carried out at Kurunneva on 10.—27.8.1987 and 1.6—31.10. in 1988 and 1989. Flow rates were measured by means of triangular Thompson's measuring weirs below the sedimentation basins, during the dredging tests in 1987 and once a day in 1988 and 1989, together with hourly

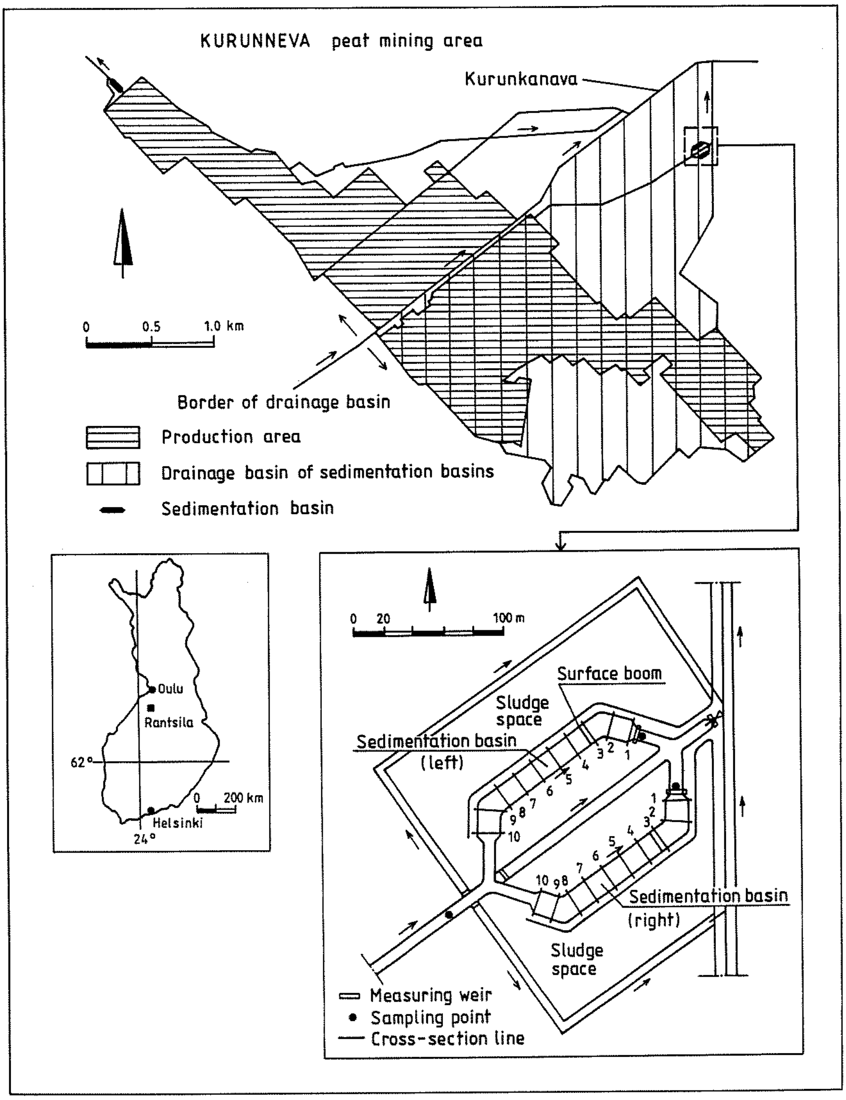

Fig. 11. Site of the sedimentation basin tests at Kurunneva.

measurements during the cleaning of the basins in 1988. Daily rainfall figures were obtained from the Meteorological Station at Haapavesi.

Water samples were obtained from the inflow channels to the sedimentation basins and the measuring weirs lying downstream of them (Fig. 11). The samples for August 1987 were collected before and during dredging and for a period of about two weeks after it, while those for 1988 and 1989 were taken at weekly intervals. All samples were examined for suspended matter, organic matter, chemical oxygen demand (COD_{Mn}), total N, NH_4—N, NO_3—N, total P, PO_4—P and total Fe, pH and colour using methods generally employed by the Finnish environmental authorities (National Board of Waters 1981).

The investigations were carried out at Murtosuo on 1.6—31.10. in 1988 and 1989. Flow rates were measured weekly at a measuring weir constructed for this purpose above the sedimentation basins and from 1989 onwards continuously by means of a water level recorder. Daily rainfall values were obtained from the Meteorological Station at Kurenala and water samples collected on a weekly basis from the measuring weir lying above the sedimentation basins and the box weirs constructed below them. The samples were analysed for suspended matter, organic matter and chemical oxygen demand (COD_{Mn}) by methods employed by the Finnish environmental authorities.

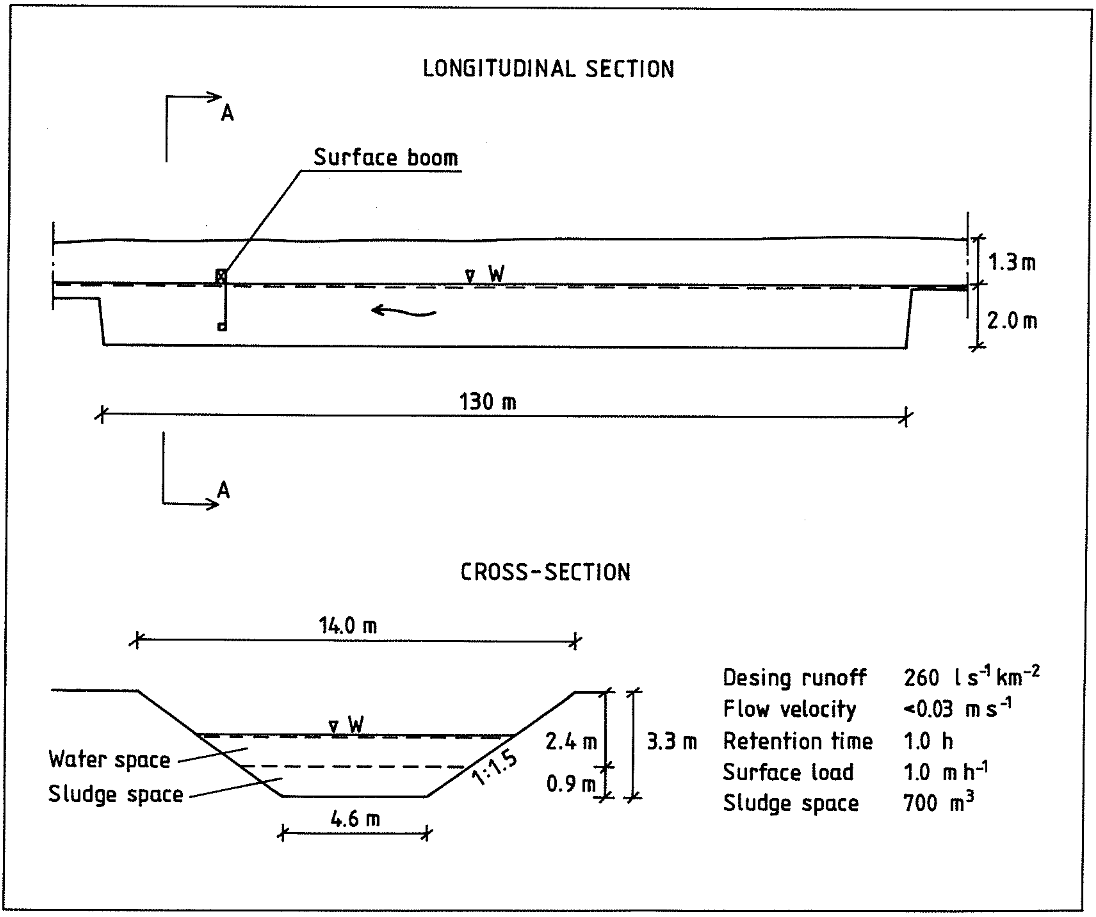

Fig. 12. Longitudinal and cross-sectional drawings of the sedimentation basins at Kurunneva, with dimensioning values.

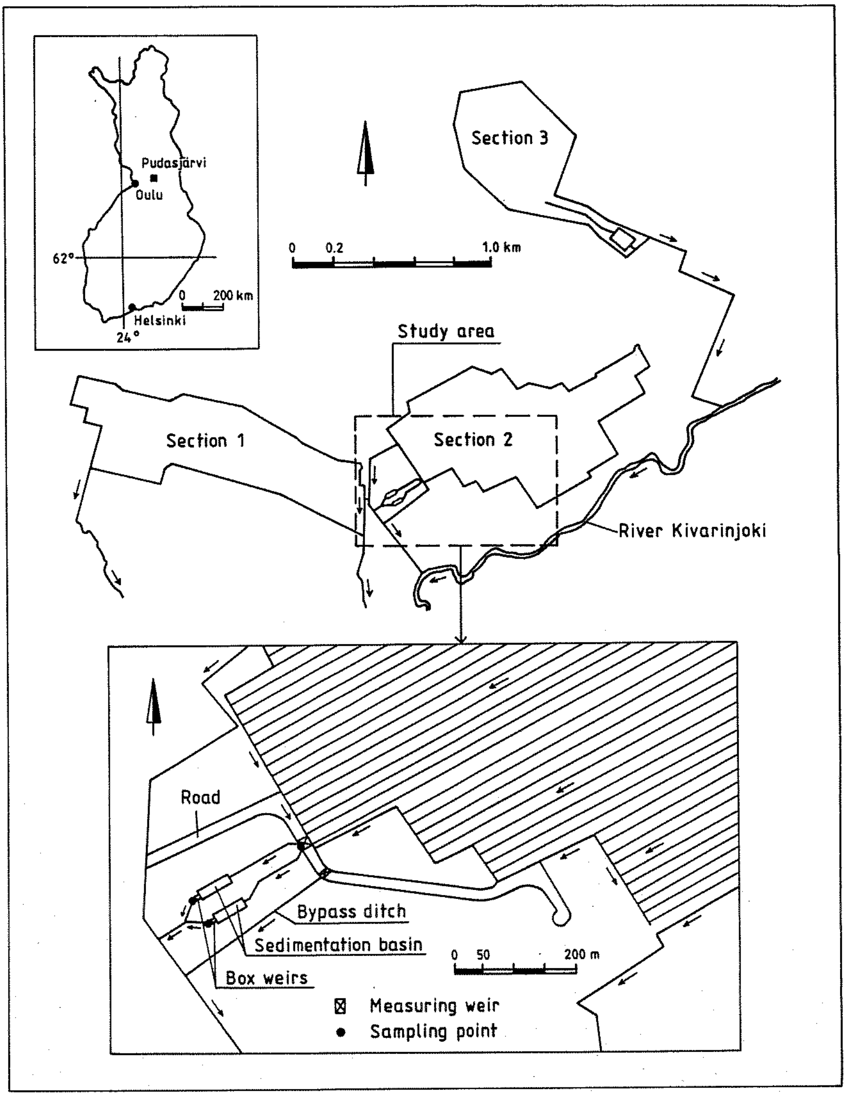

Fig. 13 Site of the sedimentation basin tests at Murtosuo.

4.4 Results and discussion

The most significant results are presented and discussed in the following The findings will be dealt with in greater detail in a more extensive report (Ihme et al. 1991d).

4.4.1 Effect of dredging frequency of sedimentation basins on loading from a peat mining area

Total rainfall during the three-year period was generally higher than the long-term averages. There were occasional downpours in the area, but also periods that were drier than average. Data were thus obtained on the practicability of the sedimentation basins at the various sites under different rainfall conditions.

Considerable variation was observed in the suspended matter, nutrient and organic matter loads imposed on the sedimentation basins (Table 7). The highest suspended matter load was observed at times of high runoff at the beginning of October 1988 and the beginning of August 1989, and the maximum organic matter and nutrient loads were found to coincide with the maximum suspended matter loads. The loads could not be calculated in terms of transport rates as the drainage area had not been determined exactly. As

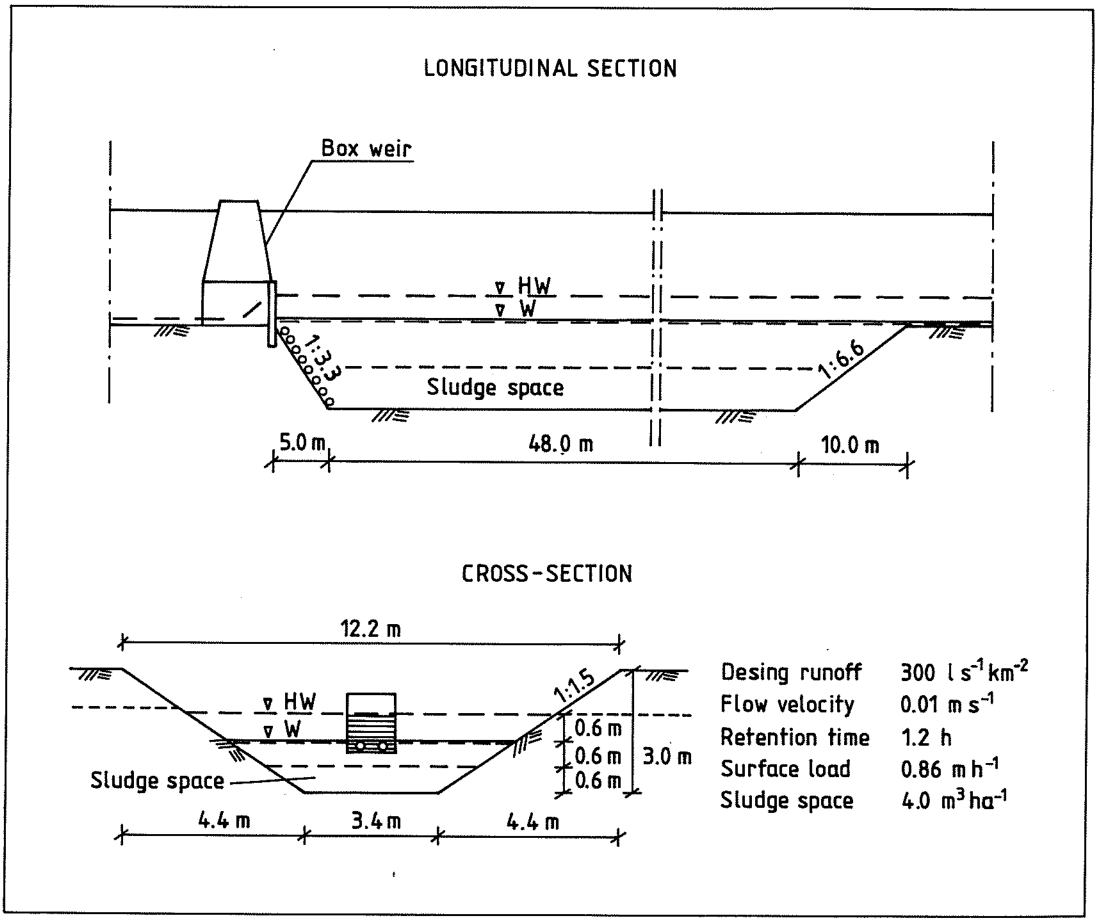

Fig. 14. Longitudinal and cross-sectional drawings of the sedimentation basins at Murtosuo, with dimensioning values.

Table 7. Average load imposed on the sedimentation basins at Kurunneva in June—October.

Parameter	Average load kg d^{-1}					
	1987[1]		1988		1989	
	Basin 1[2]	Basin 2[2]	Basin 1	Basin 2	Basin 1	Basin 2
SS	10	10	43	65	471	358
COD$_{Mn}$	23	23	38	55	182	135
Tot.N	2	2	3	4	14	11
Tot.P	0.1	0.1	0.1	0.2	0.3	0.2
Tot.Fe	8	8	10	15	21	15

[1] August 1987, [2] Basin 1 = on the left according to the flow direction, Basin 2 = on the right according to the flow direction (Fig. 11), SS = suspended solids

Table 8. Average reductions achieved in the sedimentation basins at Kurunneva.

Parameter	Average reduction %					
	1987[1]		1988		1989	
	Basin 1[2]	Basin 2[2]	Basin 1	Basin 2	Basin 1	Basin 2
SS	−216	−159	−26	17	73	73
COD$_{Mn}$	− 5	− 2	− 2	3	47	49
Tot.N	− 2	− 9	− 1	3	47	49
Tot.P	− 33	− 19	− 6	6	26	31
Tot.Fe	− 26	− 27	− 7	1	33	38

[1] August 1987, basins were dredged August 17.—26.1987, [2] Basin 1 = on the left according to the flow direction, Basin 2 = on the right according to the flow direction (Fig. 11), SS = suspended solids

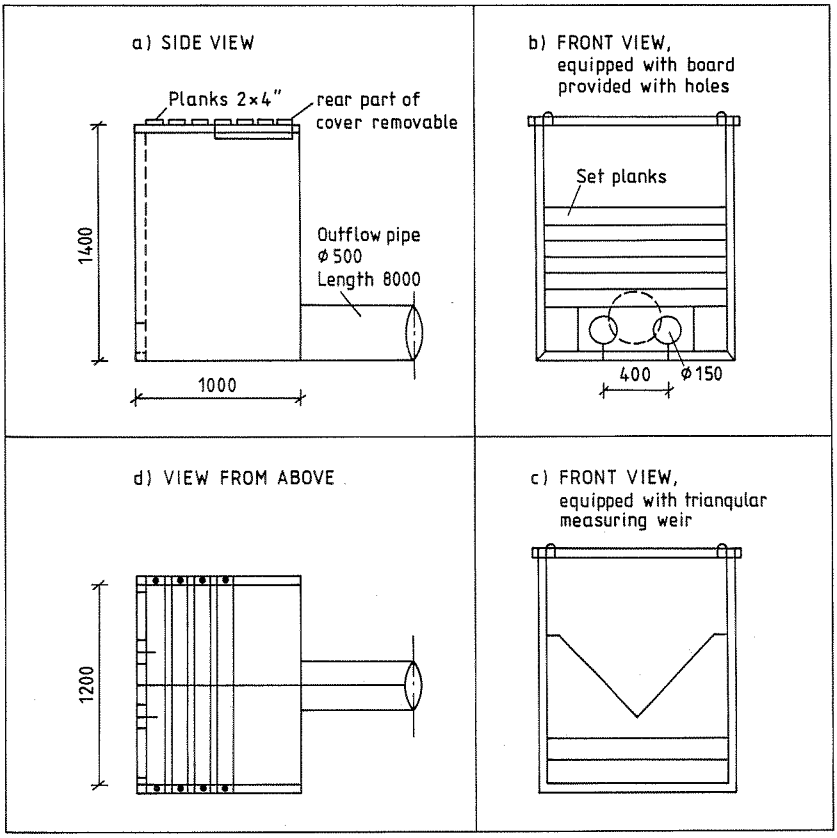

Fig. 15. Box weirs in the sedimentation basins at Murtosuo.

the samples were obtained only once a week, the loading peaks could not always be identified. The loads imposed on the sedimentation basins were of equal magnitude, even though it was not possible to distribute the runoff water evenly between them.

Dredging frequency had no appreciable effect on the suspended matter, nutrient and iron load imposed on the lower watercourse (Table 8), i.e. the reductions achieved with both sedimentation basins were of almost equal magnitude irrespective of the dredging frequency.

Since suspended matter, nutrients, particularly phosphorus, and iron leached from the sedimentation basin as a result of the dredging operations (Figs. 16, 17), the average reductions obtained in the basin dredged more frequently were slightly lower than those in the basin dredged only once a year, but the concentrations dropped to their former level, i.e. that before the dredging, within four days after the basin had been dredged.

Kurunneva is an old peat production area where the ditches extend down to the mineral soil at least in some places. There is a collection ditch of length at least one kilometre above the sedimentation basins where suspended matter could also be retented, in addition to which water coming from outside the peat mining area also flows via the basins. Sedimentation of suspended matter in the basin was occasionally impaired by turbulence in the flow. All these factors affect both the load imposed on the sedimentation basins and their purification results, and the results can thus mainly be regarded as being characteristic of this particular area only.

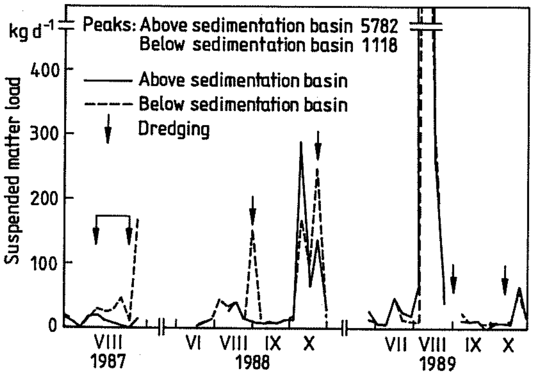

Fig. 16. Suspended matter load on the areas above and below the left-hand sedimentation basins at Kurunneva in 1987—1989. The basin was dredged three times a year.

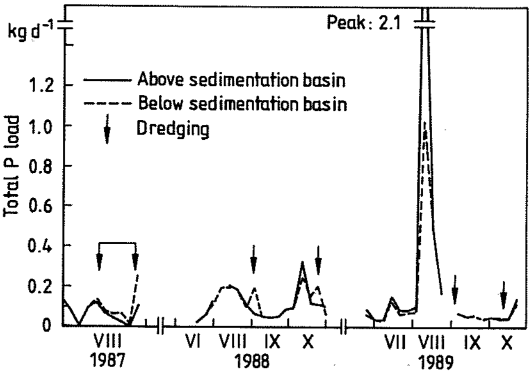

Fig. 17. Total phosphorus load on the areas above and below the left-hand sedimentation basin at Kurunneva in 1987—1989. The basin was dredged three times a year.

4.4.2 Effect of the box weir on loading from a peat mining area

The average suspended matter load imposed on the sedimentation basins by the peat mining area of Murtosuo was 5.0—15.1 kg d^{-1}, individual values varying from 2.3 to 93.4 kg d^{-1}, the corresponding figures for organic matter being 11.5—18.3 kg d^{-1} and 4.4—40.9 kg d^{-1}.

The average reductions in suspended matter recorded for the sedimentation basins equipped with box weirs were of similar magnitude to those obtained by Selin and Koskinen (1985) for sedimentation basins without box weirs during the frost-free season or lower, the latter being 30—40 % (Table 9). The basins with box weirs removed suspended matter best at times of

Table 9. Average reductions achieved in the sedimentation basins of Murtosuo in June—October 1988—1989.

Parameter	Average reduction %			
	1988		1989	
	Basin 1[1]	Basin 2[1]	Basin 1	Basin 2
SS	−15	7	42	46
COD_{Mn}	− 1	−5	−2	−7

[1] Basin 1 = on the left according to the flow direction, box weir equipped with board provided with holes, Basin 2 = on the right according to the flow direction, box weir equipped with triangular Thompson's measuring weir, SS = suspended solids

occasional high suspended matter loads, whereas no appreciable effect was observed in the case of lower loads. The reductions achieved were of almost equal magnitude in both sedimentation basins, one of which was equipped with a box weir carrying a triangular measuring weir and the other a board with holes in it.

It was impossible to reduce the organic matter load by providing the sedimentation basins with box weirs, and the load often seemed to increase slightly in the basins (Table 9).

Box weirs provide a better solution in terms of practicability than a drum structure, for example, which has been used as a weir construction for the outlet end of sedimentation basins. A thermally insulated box weir allows the runoff water to flow through even in winter, i.e. the water will not erode the soil around the box and thus impose an additional load on the lakes and rivers downstream. This will reduce the need to improve the outlet constructions established at the lower end of the basin. The surface width of the sedimentation basin will decrease when a box weir is used, and the basin will thus become easier to clean and its space requirement will decrease. It can also be constructed 0.5—1.5 m lower than an ordinary basin.

4.5 Planning, construction, management and costs of sedimentation basins

The field surveys necessary for the construction of a sedimentation basin should be carried out in connection with those required for ditching work and the geomorphological and hydrological examinations. Various alternative sites should be considered for the sedimentation basin if necessary.

The dimensions of sedimentation basins should follow the supervision regulations issued by the Finnish environmental authorities (1990). A bypass system should be constructed in the immediate vicinity of the sedimentation basin to conduct the runoff water past it, if necessary. The basin should generally be located on the edge of the peat mining area or in connection with the outlet ditch and should be outside the flood area. The basin can be kept in a better condition if it is constructed on peat soil than on coarse-grained soil or on silt. A storage area should be provided for the sludge collected from the sedimentation basin, and if numerous basins are to be constructed in the drainage area, these should be located as near each other as possible to facilitate observation and servicing. Proper access to the basins should be provided.

Constructions which can be added to sedimentation basins are a flood distributor/sluice gate, and stilling lattice, a surface boom, a weir at the outlet, and a measuring weir. The structures should be practicable, durable, simple, and as easy to manufacture, install and service as possible.

The box weir at Murtosuo proved a very practicable construction: it reduced the surface width of the sedimentation basin, which in turn made it easier to clean and reduced the space required. As the flow rate in a sedimentation basin with a box weir is practically constant, excessive delays will be prevented.

The sedimentation basin and all the necessary structures should be established at their permanent sites before the pre-drainage phase or any ditching work preceding the actual drainage. The ditching work should be carried out during as dry periods as possible.

The sedimentation basins and all the related structures should be serviced regularly in order to ensure as efficient purification of the runoff water as possible. The basins should be dredged when necessary, and at least once a year. The outlet should be closed for the dredging period to prevent the sludge from passing into the lakes and rivers downstream. The basins are usually dredged by means of an excavator, and a suction dredger has also been developed for this purpose.

The costs arising from sedimentation basins equipped with a box weir are lower than those caused by ordinary sedimentation basin, as the former are shallower, require less space and entail lower maintenance costs. The costs of an ordinary sedimentation basin are 450—880 FIM ha^{-1} at the 1988 price level (Selin and Koskinen 1985).

5 SUMMARY

The aim of the research project "Development of water pollution control technology in peat mining" was to develop new methods and improve those already in use to reduce the loading of watercourses from mires at the various stages in peat mining. The project was carried out by the Ministry of Trade and Industry, the peat producers, the water authorities, the Building Laboratory of the Technical Research Centre of Finland and the University of Oulu in 1987—1990, the field investigations taking place in 1987—1989. Factors examined were the use of overland flow and filtration for the purification of runoff water, load retention by means of field ditches and improvement of the practicability and dredging of sedimentation basins. The tests were all performed at sites in the Province of Oulu.

In addition to suspended matter, a peat filter also allows the removal of nutrients from the runoff water from peat mining areas, although its use often increases phosphorus concentrations in the water. Peat filters tend to clog very rapidly, which hampers their use, and there is as yet no satisfactory mechanical method for cleaning them. The duration of the longest continuous raw peat filtration period was about two weeks, employing a filter with a thickness of 0.4 m and a surface laod of 0.5 m h^{-1}. A peat filter should be monitored almost daily to prevent it from clogging.

The suspended matter content of the water issuing from a peat mining area could be reduced by means of retention pipes, but these had no effect on nutrient concentrations.

The frequency of dredging a sedimentation basin had no significant effect on the suspended matter, nutrient and iron load caused by peat mining, and these substances even leached from the sedimentation basin as a result of dredging. In fact the average reductions achieved in a basin dredged more frequently were slightly lower than those in a basin dredged only once a year. Results can mainly be regarded as being characteristic of this particular area only.

The average rate of removal of suspended matter could not be improved by means of a discharge device, i.e. a box weir, constructed at the lower end of the sedimentation basin. Sedimentation basins equipped with such a device removed suspended matter best during occasional high suspended matter loads, but had no appreciable effect on small loads.

The box weir distributes the flow rates in the sedimentation basin more evenly and reduces erosion of the slopes at the discharge end. It also reduces the surfaces width of the basin and thus makes it easier to clean and reduces the space needed.

The findings were used to draw up instructions for the planning, construction and management of the structures examined.

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YHTEENVETO

"Turvetuotannon vesiensuojeluteknologian kehittäminen"-projektin tavoitteena oli kehittää uusia menetelmiä ja parantaa jo olemassa olevia menetelmiä turvetuotannon vesistökuormituksen vähentämiseksi. Tutkimus toteutettiin vuosina 1987—1990. Kenttätutkimuksia tehtiin vuosina 1987—1989. Projektin toteutukseen osallistuivat kauppa- ja teollisuusministeriö, turvetuottajat, vesiensuojeluviranomaiset, valtion teknillisen tutkimuskeskuksen rakennuslaboratorio ja Oulun yliopisto. Projektin osatutkimuksia olivat pintavalutuksen käyttö valumavesien puhdistamisessa, suodatuksen käyttö valumavesien puhdistamisessa, kuormituksen pidättäminen sarkaojiin ja laskeutusaltaiden toimivuuden ja puhdistettavuuden parantaminen. Tutkimuskohteet sijaitsevat Oulun läänissä.

Turvesuodattimella saadaan poistettua turvetuotantoalueelta valuvasta vedestä kiintoaineen lisäksi myös ravinteita. Valumaveden fosforipitoisuudet usein kuitenkin myös lisääntyivät suodatuksen seurauksena. Turvesuodattimet tukkeutuvat varsin nopeasti, mikä haittaa niiden käyttöä. Turvesuodattimen pinnan puhdistamiseen ei ole käytettävissä hyvää koneellista menetelmää. Pisin yhtäjaksoinen palaturvesuodatus kesti noin kaksi viikkoa. Palaturvesuodatinkerroksen paksuus oli 0,4 m ja pintakuorma 0,5 m h^{-1}. Tukkeutumisen vuoksi turvesuodattimia tulisi tarkkailla lähes vuorokausittain.

Päisteputkipidättimillä voitiin pienentää turvetuotantoalueelta valuvan veden kiintoainespitoisuutta. Sen sijaan valumaveden ravinnepitoisuuksiin ei erilaisilla pidätintyypeillä ollut vaikutusta.

Laskeutusaltaan puhdistustiheydellä ei ollut merkittävää vaikutusta turvetuotannon kiintoaines-, ravinne- ja rautakuormitukseen. Altaasta huuhtoutui kiintoainesta, ravinteita ja rautaa ruoppauksen

vuoksi. Toisaalta keskimääräiset poistumat useammin ruopatussa altaassa olivat hiukan pienemmät kuin kerran vuodessa ruopatussa altaassa. Laskeutusaltaan alapäähän rakennetulla purkulaitteella, ns. patolaatikolla, ei saatu parannetuksi laskeutusaltaiden keskimääräistä kiintoainespoistumaa. Patolaatikolla varustetut laskeutusaltaat poistivat kiintoainesta parhaiten ajoittaisten suurten kiintoaineskuormitusten aikana. Niillä ei sen sijaan ollut merkittävää vaikutusta pieniin kiintoaineskuormiin. Patolaatikko tasaa laskeutusaltaan virtaamia ja vähentää laskeutusaltaan purkupään luiskien syöpymistä. Patolaatikkoa käytettäessä laskeutusaltaan pintaleveys pienenee, jolloin altaan puhdistettavuus paranee ja tilan tarve vähenee.

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