Vol. 9 (2000): 217–221.

Research Note

Phosphorus content of ditch sediments as indicator of critical source areas

Håkan Jansson
Agricultural Research Centre of Finland, Resource Management Research, FIN-31600 Jokioinen, Finland, e-mail: hakan.jansson@mtt.fi
Väinö Mäntylahti
Soil Testing Service Ltd, FIN-50101 Mikkeli, Finland
Aaro Närvänen, Risto Uusitalo
Agricultural Research Centre of Finland, Resource Management Research, FIN-31600 Jokioinen, Finland

An inexpensive method for identifying high phosphorus (P) loads on ditches carrying water from critical source areas ("hot spots", i.e. manure-affected areas) was tested. Water flowing from the hot-spot areas is rich in dissolved nutrients (e.g. P) and nutrient-rich eroded material. In this study the water from hot spots contained an average of 2.2 mg/l dissolved reactive P but field ditch water 0.14 mg/l. We selected 62 ditches with varying P-load levels for sediment analysis. Five ponds and 16 lakes were also studied. The sediment samples were analysed by the AAAc-extraction (0.5 M ammonium acetate, 0.5 M acetic acid, pH 4.65) method used for routine soil testing in Finland. The analysis of sediment AAAc-P proved to be a useful method for identifying ditches carrying high P waters from hot spots. Half of the ditch sediments in the hot spot ditches showed high or excessive P concentrations. AAAc extraction of the sediment is less expensive than water analysis and the sampling can be extended to periods when no water flows in the ditches.

Key words: phosphorus, environmental control, ditches, catchment areas, sediment testing, acid ammonium acetate extraction

Introduction

Phosphorus (P) is the nutrient limiting algal growth in most lakes and rivers in Finland (Pietiläinen 1997). Although the P load from rural catchments is strongly positively correlated with the agricultural field area (Rekolainen 1989), it varies widely from field to field. Phosphorus losses from arable land clearly depend on the soil test P level (Turtola and Yli-Halla 1999). Sallade and Sims (1997) reported that the P con-

Manuscript received April 2000

centrations (Melich-1) in agricultural sediments decreased with depth. The P concentrations they found were about the same as in the topsoil of the fields.

In addition to the well documented P load from cultivated fields, small areas with a high soil P concentration may generate a high P concentration in runoff (Sharpley et al. 1998, Torpey et al. 1998, Sharpley and Rekolainen 1998). Known as "hot spots", these areas are typically loaded by farmyard manure (i.e. manure from barnyards, waste storage areas, paddocks, feeding and salt licking areas for grazing animals, milking sheds) or household wastewater. In the lake Rehtijärvi study (Jansson 1998), the importance of hot spots for the P load became obvious on catchment scale because their contribution to the annual load of dissolved P in the lake Rehtijärvi catchment area was 53%. A first step in lake restoration is to cut down the external P load. To do that, one should identify all significant P sources. This can be done by tracing the P-rich waters entering a lake.

When water is analysed to identify high P load areas, the shortness of the peak flow periods that can be used for this type of survey poses a problem. We therefore tested an alternative method for identifying ditches with a high P load and analysed ditch sediment with the aid of acid ammonium acetate buffer as used for routine soil testing in Finland (Vuorinen and Mäkitie 1955). We compared the extractable P in ditch sediment with the P concentration in ditch water during high flow periods in areas of different land use by assuming that the sediment gradually equilibrates with the water running in the ditch. Since the sediment has a strong buffer capacity against changes in the P concentration of water, the sediment P concentration is a more stable parameter than is the P concentration of water. Therefore, the P concentration of the ditch sediment can be used to predict the average P concentration of the ditch water, provided that the P concentration of the water remains the same as it was when the sediment equilibrated with the water.

Material and methods

The study was carried out in the vicinity of Jokioinen, southwestern Finland, in an area with mainly clayey soils. The sediment samples were taken from small ditches in summer 1998; sampling from lakes and sedimentation ponds started earlier the same year. The equipment used for summer and winter sampling is illustrated at the web pages of the life for Lakes project (Agricultural Research Centre of Finland and Agropolis 2000). The plastic tube used for winter sampling had an inner diameter of 4 cm and a length of 2 m, and was lowered through a hole made in the ice. The samples from lakes and sedimentation ponds were taken at sites where the water depth did not exceed 2 m. The tube was pressed into the bottom sediment to a depth of 5 to 15 cm. A bottom plug with a rope prevented the sediment from slipping out of the sampler when lifted up. The water was removed from the tube through holes at the 20 cm height of the tube. In small ditches, the sediment samples were taken with a scoop. In ditches the sampled layer ranged from 2 to 7 cm in thickness. Two to ten subsamples were combined to form a sample for analysis.

The samples were analysed by the soil testing method commonly used in Finland (Vuorinen and Mäkitie 1955). The sediment was air-dried and passed through a 2-mm sieve and extracted for 1 h in a 0.5 M ammonium acetate 0.5 M acetic acid (AAAc) solution (pH 4.65). For extraction, 25 ml of sediment was placed in 250 ml of AAAc solution. The extraction time was 1 h. P was determined colorimetrically from the filtered extracts by a molybdenum blue method with stannous chloride as the reducing agent. This Finnish acid ammonium acetate-extraction method resembles Morgan extraction.

Water samples from most of the ditches, lakes and ponds were taken in 1994–1998. The main emphasis was on peak runoff periods but samples were also taken during low water flow periods. The water flow rate in open ditches was estimated from the speed of the water and the water cross-section. Dissolved P was determined

Vol. 9 (2000): 217–221.

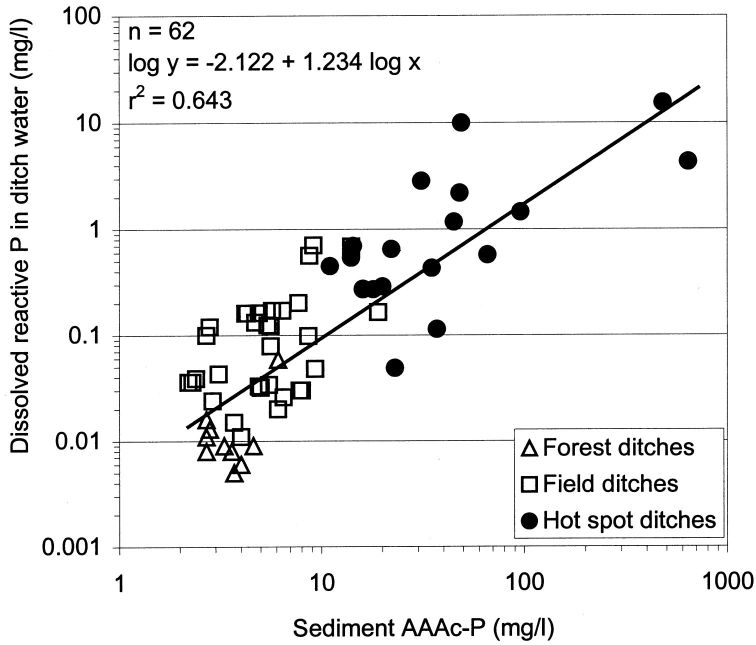

Fig. 1. Dissolved reactive P in ditch water as a function of phosphorus extracted with ammonium acetate in ditch sediments. The "hot spot ditches" refer to ditches at dairy farms and in horse stable areas, and to wastewater-affected ditches.

by filtering the water samples through a membrane filter (0.45 µm), whereas total P was determined by digesting unfiltered subsamples with peroxodisulphate in an autoclave, as described by Uusi-Kämppä and Yläranta (1996).

Results and discussion

Seven of the sediment P concentrations measured (Fig. 1) would be classified as excessive (> 40 mg/l of soil), three as high (25–40 mg/l) and 15 as relatively low (< 4 mg/l) according to the Finnish fertility classification for soil. Generally, excessive sediment P concentrations (up to 600 mg/l) were found in ditches that contained water originating from hot spots, and low extractable P concentrations in ditches where the water had a low P concentration (Fig. 1), in good agreement with the P load. In this study only some of the water and ditch sediments were sampled simultaneously but the land use activities around the ditches studied remained constant. The highest P concentrations were found in water and sediments sampled in critical source areas on dairy farms (Table 1). Most of the total P in water from these areas was in dissolved reactive form, and the concentration was six times higher than in ditches affected by household wastewater. The same applied to the AAAc-extractable P in their sediments. The P concentrations were slightly lower in sediments and water originating from horse stable areas than in wastewater ditches.

The dissolved P concentrations measured in runoff from arable fields in this study were about one tenth of those in water from the critical source areas, and in good agreement with the P levels reported in runoff from agricultural areas in Finland (Rekolainen 1989). The extractable P concentrations of the respective sediments were lower than those in the topsoil of Finnish fields. In 1991–1995, the mean AAAc-extractable P concentration in the cultivated soils of Finland was reported to be 12.4 mg/l (Mäntylahti, unpublished). The low P concentration of the field

Table 1. Phosphorus extracted with acid ammonium acetate (mean ±SD) in sediments from lakes, ponds and different kinds of ditches, and the average concentrations of dissolved and total phosphorus in water sampled from the same sites.

	n	AAAc-P in sediment		Dissolved P in water		Total P in water	
		mg/l					
Lake	16	5.1	±2.9	0.013	±0.008	0.066	±0.076
Sedimentation pond	5	8.3	±4.5	0.145	±0.118	0.347	±0.186
Forest ditch	10	3.7	±1.1	0.014	±0.017	0.056	±0.025
Field ditch	33	6.0	±3.4	0.138	±0.177	0.387	±0.252
Horse stable area ditch	7	21.6	±13.0	0.550	±0.315	1.28	±0.838
Wastewater affected ditch	6	34.3	±19.0	1.04	±1.18	1.38	±1.32
Dairy farm ditch (critical source areas)	6	221	±269	5.3	±6.1	5.9	±6.2

AAAc-P = phosphorus extracted with acid ammonium acetate method

ditch sediments is attributed to the low AAAc-extractable P in the main sampling area, the catchment area of lake Rehtijärvi (Jansson 1998). The sediment analysis was, however, sensitive enough to show the difference in P concentrations between field and forest ditch waters. In lakes, the AAAc-extractable P was consistent with the dissolved reactive phosphorus concentrations in water. The above results suggest that AAAc extraction of ditch sediments is a promising method for locating high P-load areas. However, it has been used locally only and still needs to be tested in areas with varying soil texture, pH and organic soil content. To enable us to make more precise recommendations about sediment sampling, the method should also be studied in greater detail, as it is important to know in which part and at what depth of a ditch the samples should be taken.

References

Agricultural Research Centre of Finland and Agropolis 2000. Life for Lakes. Pictures illiustrating sediment sampling. Available from Internet: http://www.mtt.fi/lifeforlakes/indexeng.html

Jansson, H. 1998. *Rehtijärvi.* In: Loimijoki-projektin raportti 1991–1997: ympäristöhankkeen eteneminen Loimijokilaakson maatiloilla ja jokirannoilla (Summary: *Rehtijärvi.* In: The Loimijoki-project report 1991–1997). Maatalouden tutkimuskeskus, Jokioinen. p. 43–48.

Pietiläinen, O.P. 1997. Agricultural phosphorus load and phosphorus as a limiting factor for algal growth in Finnish lakes and rivers. In: Tunney, H. et al. (eds.). *Phosphorus loss from soil to water*. p. 354–356.

Rekolainen, S. 1989. Phosphorus and nitrogen load from forest and agricultural areas in Finland. *Aqua Fennica* 19: 95–107.

Sharpley, A., Gburek, W. & Heathwaite, L. 1998. Agricultural phosphorus and water quality: sources, transport and management. *Agricultural and Food Science in Finland* 7: 297–314.

– & Rekolainen, S. 1998. Phosphorus in agriculture and its environmental implications. In: Tunney, H. et al. (eds.). *Phosphorus loss from soil to water*. p. 1–53.

Torpey, P., Calvin, D. & Morgan, M.A. 1998. Phosphorus loss in farm drainage. *Proceedings of the World Congress of Soil Science*. Sci. reg.: 2177. Montpellier, France.

Turtola, E. & Yli-Halla, M. 1999. Fate of phosphorus applied in slurry and mineral fertilizer: accumulation in soil and release into surface runoff water. *Nutrient Cycling in Agroecosystems* 55, 2: 165–174.

Uusi-Kämppä, J. & Yläranta, T. 1996. Effect of buffer strips on controlling soil erosion and nutrient losses in southern Finland. In: Mulamoottil, G. et al. (eds.). *Wetlands environmental gradients boundaries, and buffers*. CRC Press, Boca Raton, Florida. p. 221–235.

Vuorinen, J. & Mäkitie, O. 1955. The method of soil testing in use in Finland. *Agrogeological Publications* 63: 1–44.

Vol. 9 (2000): 217–221.

SELOSTUS

Kilpailukykyinen menetelmä pistemäisten fosforikuormitusalueiden paikantamiseen

Håkan Jansson, Väinö Mäntylahti, Aaro Närvänen ja Risto Uusitalo
Maatalouden tutkimuskeskus ja Viljavuuspalvelu Oy

Tässä tutkimuksessa kehitettiin hinnaltaan kilpailukykyinen menetelmä pistemäisten fosforikuormitusalueiden paikantamiseen. Pistemäisiltä kuormitusalueilta tulevan veden liukoisten ravinteiden pitoisuudet ovat suuria ja veden kuljettama eroosioaines on runsasravinteista.

Pistemäisten kuormituspisteiden veden liuenneen fosforin pitoisuus oli keskimäärin 2,2 mg/l ja peltoveden keskimäärin 0,14 mg/l tässä tutkimuksessa. Tutkimusaineistona olleista ojista valittiin 62 fosforikuormitukseltaan erilaista ojaa edelleen sedimenttitutkimukseen. Sedimenttinäytteet analysoitiin Suomessa käytössä olevalla viljavuusanalyysimenetelmällä.

Ojasedimenttianalyysimenetelmä osoittautui hyväksi menetelmäksi, jolla voidaan paikantaa ojista tulevia korkeita fosforikuormituksia. Puolet kuormitusojien sedimentin fosforipitoisuuksista olivat viljavuusluokituksen mukaan ”korkeita” tai ”arveluttavan korkeita”. Fosforikuormituksen arviointi sedimenttianalyysimenetelmällä on edullisempaa kuin vesianalyysillä. Sedimenttimenetelmää voidaan käyttää myös silloin kun tutkittavat ojat ovat kuivia. Lisäksi menetelmän laboratoriokustannukset ovat edulliset.