Novel methods for reducing agricultural nutrient loading and eutrophication

14-16 June 2010, Jokioinen

COST869, Working groups 2 and 3

Field excursions

K. Rasa (Ed.)

Monday, June 14, MTT. Kotkanoja experimental fields

Of the Kotkanoja experimental fields, the Field 1 was established in 1975 and reconstructed in 1991 (Fig 1 and 2). The Field 2 field was established in 1991 (Fig 1 and 3). The fields have been mainly used to study nutrient losses, including the effects of various tillage depths and currently no-till in Field 1, and the effects of slurry applications in Field 2. The soil is Vertic Cambisol typical for southwestern Finland. The soil has a high clay content (60% at the surface, up to 90% at the about 1 m drainage depth) which means that percolation is limited, and much of the horizontal flow occurs as near-surface flow, and vertical flow as macropore flow. The mean slope of the fields is 2.6% varying between about 1 and 4%. Annual precipitation in the area is around 600mm.

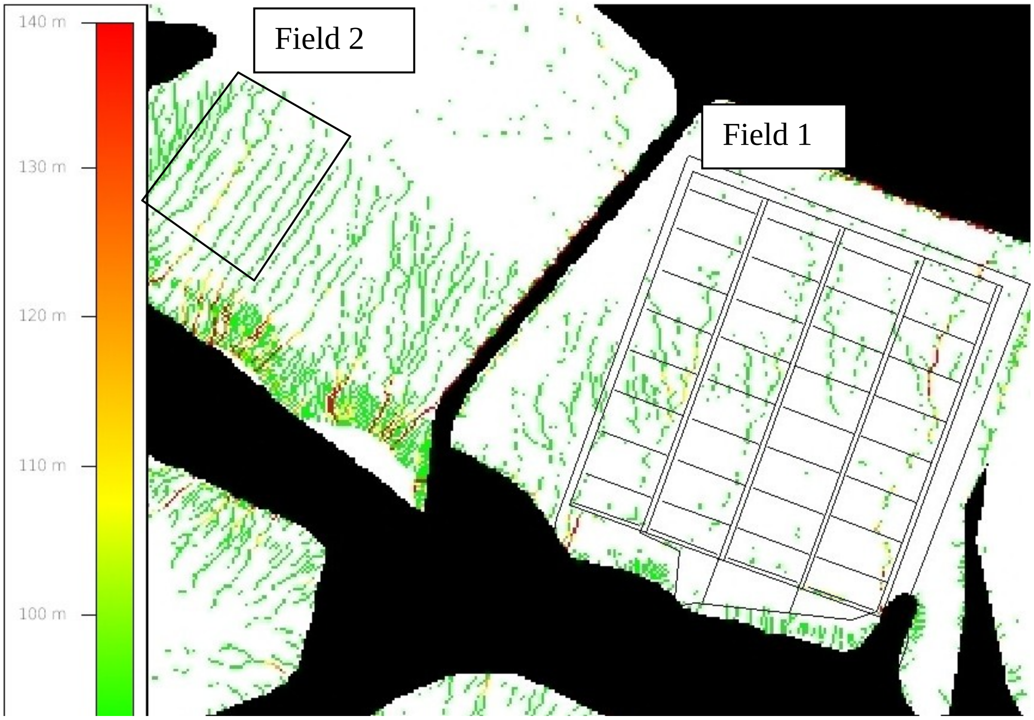


Figure 1. Relative RUSLE erosion map of the Kotkanoja fields. Red colour indicate a high erosion risk.

Set-up of the Kotkanoja fields

The Field 1 consists of 4 main plots (33 m × 140 m), each of which is further divided into 4 subplots (33 m × 33 m). The treatments are run at the main plot scale, and since 1992 there have been two replicated treatments in each experiment. Surface runoff collection is done on the main plots with collectors installed at the lower edge of the field (in Fig. 2, collectors A–D). Each of the subplots (Fig 2, labelled 1–16) is equipped with separate pipe system, allowing subplot-wise measurement and analyses of drainage water. All water draining from the field is conducted into a sampling building, where flow measurement and water sampling by the means of a tipping bucket arrangement takes place. The field was originally drained in 1962, with a first renovation taking place in 1975. In 1991, when the tile drainage was negligible (20% of total runoff), the field was built in its current shape. The field will be installed with automatic turbidity measurement of runoff during summer 2010.

E. Turtola, A. Paajanen / Agricultural Water Management 28 (1995) 295–310

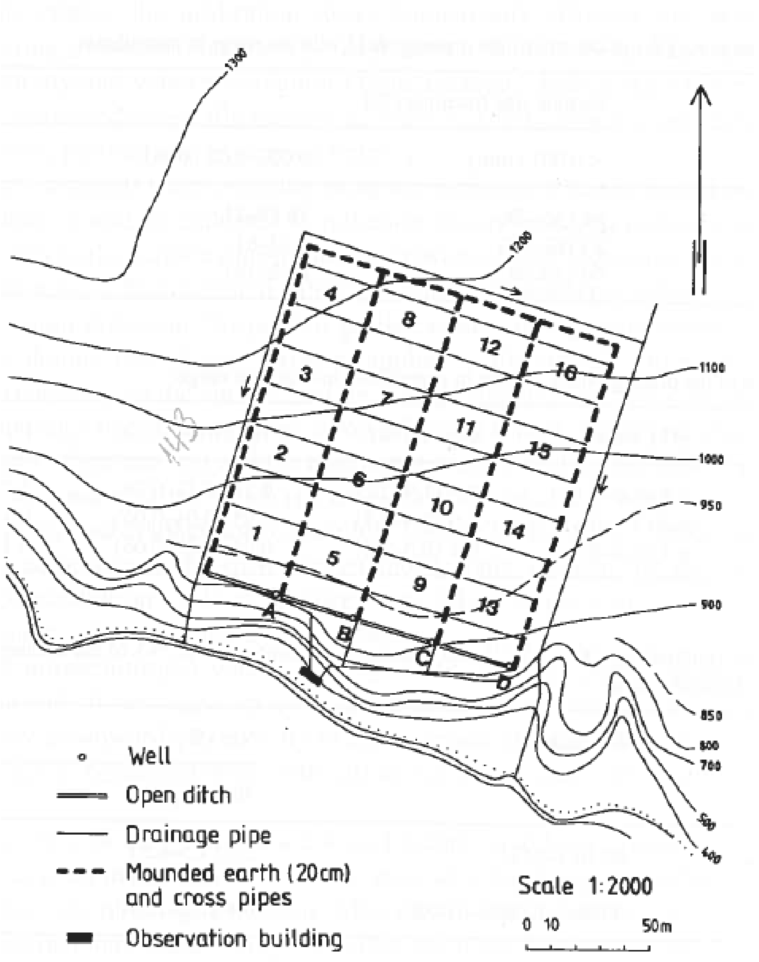


Figure 2. Schematic presentation of the Field 1.

Further information on the experiments and soil properties of Field 1 is found in the following publications:

TURTOLA, E., ALAKUKKU, L., UUSITALO, R. & KASEVA, A. 2007. Surface runoff, subsurface drainflow and soil erosion as affected by tillage in a clayey Finnish soil. Agricultural and Food Science 16(4): 332-351.

UUSITALO, R., TURTOLA, E. & LEMOLA, R. 2007. Phosphorus losses from a subdrained clayey soil as affected by cultivation practices. Agricultural and Food Science 16(4):352-365.

UUSITALO, R., TURTOLA, E., PUUSTINEN, M., PAASONEN-KIVEKÄS, M. & UUSI-KÄMPPÄ, J. 2003. Contribution of particulate phosphorus to runoff phosphorus bioavailability. Journal of Environmental Quality 32: 2007-2016.

PELTOVUORI, T., UUSITALO, R: & KAUPPILA, T. 2002. Phosphorus reserves and apparent phosphorus saturaton in four weakly developed cultivated pedons. Geoderma 110: 35-47.

UUSITALO, R., TURTOLA, E., KAUPPILA, T. & LILJA, T. 2001. Particulate phosphorus and sediment in surface runoff and drainflow from clayey soils. Journal of environmental quality 30, 2: 589-595.

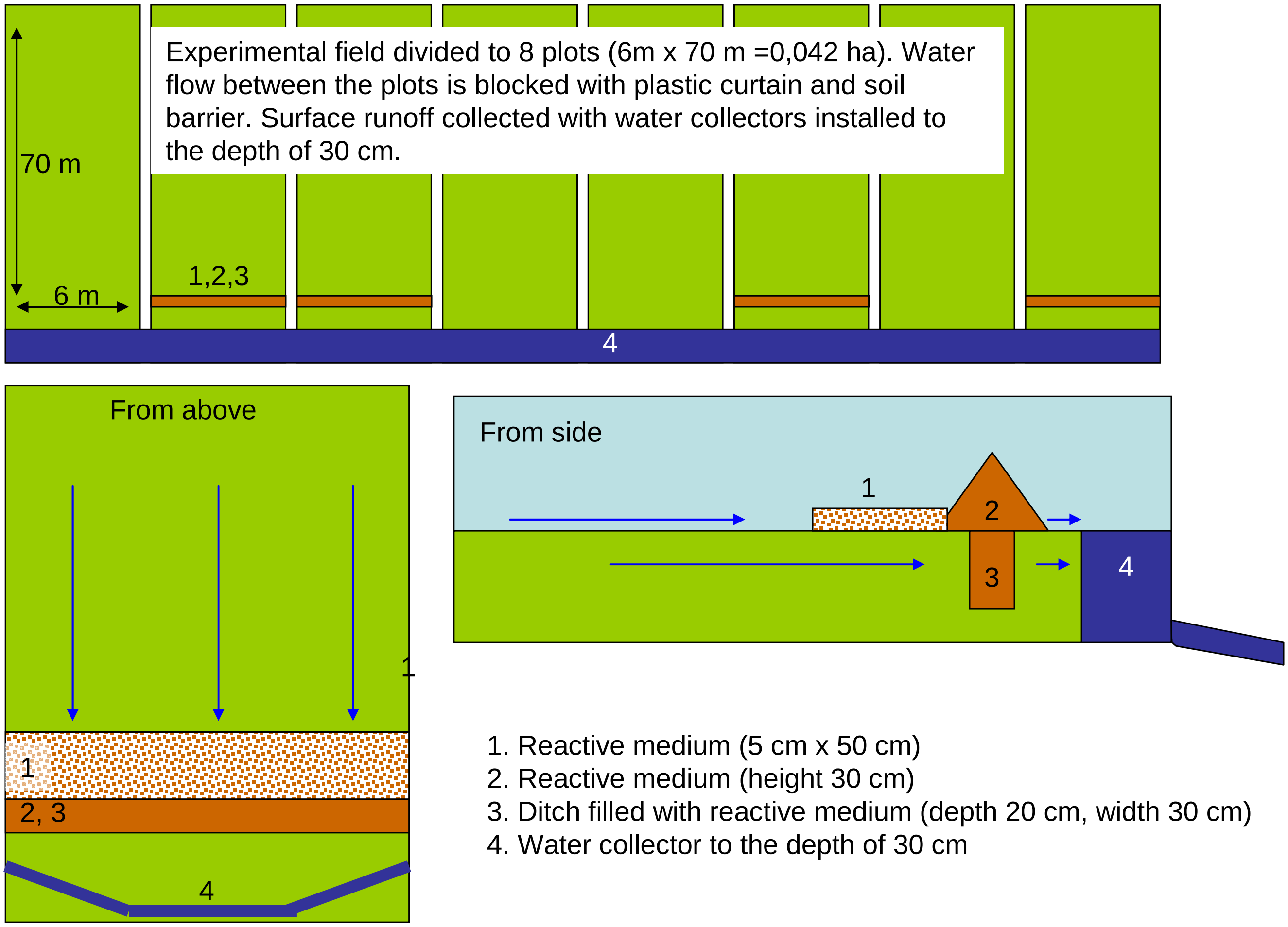
TURTOLA, E. & JAAKKOLA, J. 1995. Loss of phosphorus by surface runoff and leaching from a heavy clay soil under barley and grass ley in Finland. Acta Agriculturae Scandinavica. Section B Soil and plant science 45: 159-165.

TURTOLA, E. & PAAJANEN, A. 1995. Influence of improved subsurface drainage on phosphorus losses and nitrogen leaching from a heavy clay soil. Agricultural Water Management 28, 4: 295-310.

The Field 2 is divided into eight parallel plots (Fig 3). Water flow between the plots is blocked with plastic curtains (to 60 cm depth) and soil barriers on the surface. At the lower edge of the field, eight water collectors are installed to the depth of 30 cm (collects surface and near-surface flow). From the collectors, water is led to 3 m^3 tanks buried into the bank below. However, the Field 2 has not been used for several years, and the sampling system will be remodelled. After construction work, the flow measurement will be based on automatic pressure sensors witch detect water level continuously in a sampling well, where automatic sampling device taking time-integrated samplers is to be installed (Fig. 4).

Experiment with edge-of-field reactive permeable barriers (Field 2, 2010-)

The aim of the experiment is to evaluate effectiveness of the Sachtofer PR Ca-Fe granules, and possibly also other similar media, to reduce P (esp. DRP) losses via surface and near-surface runoff in an edge-of-field setup. The materials will be selected after laboratory studies. However, high quantities of water during snowmelt will impose a major challenge.



Experimental field divided to 8 plots (6m x 70 m =0,042 ha). Water flow between the plots is blocked with plastic curtain and soil barrier. Surface runoff collected with water collectors installed to the depth of 30 cm.

1. Reactive medium (5 cm x 50 cm)
2. Reactive medium (height 30 cm)
3. Ditch filled with reactive medium (depth 20 cm, width 30 cm)
4. Water collector to the depth of 30 cm

Figure 3. Schematic presentation of the Field 2.

Planned set-up of the experiment will consist, depending on the number of selected media, of 2–4 control plots and 2–4 plots with a P retention barrier. The reactive media will be placed into a shallow ditch (length 6 m, depth 0.2 m, width 0.3 m) at the margin of the plot (Fig. 3). Above the ditch filled with the reactive media, a 30 cm high pile of the media will be constructed to treat surface runoff. Moreover, a thin (about 5 cm) layer of the media will be distributed in front of the pile in order to provide longer contact period between surface runoff and the media.

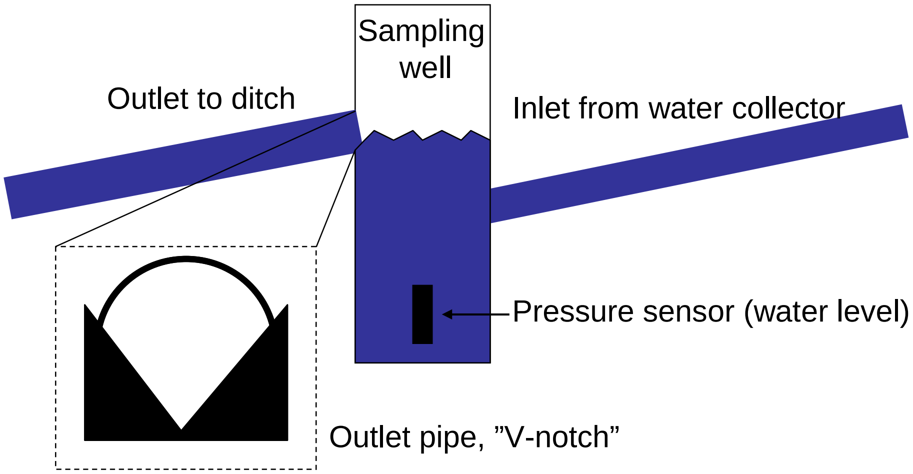


Figure 4. A sketch of sampling well and flow measurement. The outlet pipe is equipped with a v-notch in order to make flow measurement more precise during low flow.

Further information on the experiments and soil properties of Field 2 is found in the following publications:

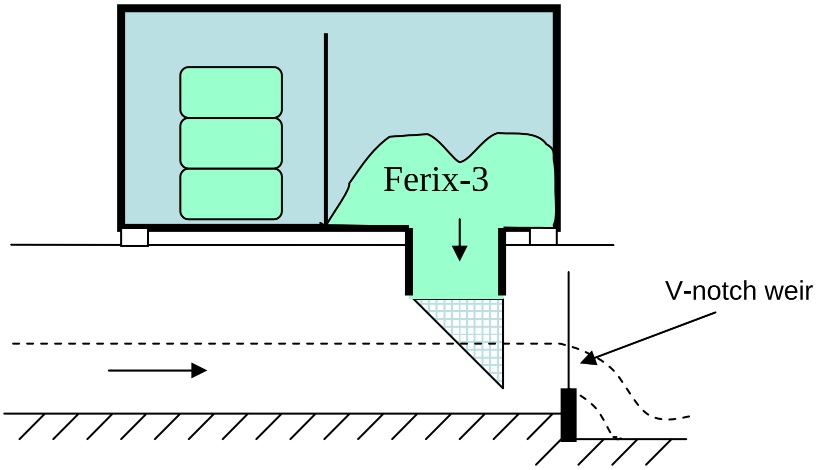
UUSI-KÄMPPÄ, J. & HEINONEN-TANSKI, H. 2008. Phosphorus and nitrogen losses to surface waters from a forested feedlot for bulls in Finland. Soil use and Management 23: 82-91.

UUSI-KÄMPPÄ, J. & MATTILA, P.K. Nitrogen losses after cattle slurry broadcast and shallow injection to grass ley. Submitted to Agricultural and Food Science.

Monday, June 14, MTT. Elonkierto area, two options to treat ditch water from hot-spots of P loading

Ferric sulphate dozer. Ferric sulphate is commonly used in waterworks and wastewater treatment plants to precipitate solids, organics, and P. The same chemical is also useful in P stripping from runoff waters. However, the dozers in runoff applications need to be simple and as maintenance-free as possible. In the Elonkierto area, we present one possible solution for runoff treatment in a ditch (Fig. 5). It consists of a container with a piece of pipe led through its bottom, and a cone-shaped netting bag attached to the end of the pipe. The container is filled with granular ferric sulphate (e.g. Ferix-3 manufactured by Kemira Chemicals Ltd.), that dissolves from the cone at a speed that depends on the surface area exposed to water (i.e., water level in front of the v-notch weir). The dozer can be scaled up and down for different ditches by simply changing a different-sized pipe and netting cone, and fine-tuned by adjusting the angle of the v-notch weir.
According to our experiences, a doze that drops pH of runoff water by 0.5 units is adequate for precipitating up to 95% of DRP in runoff. For flocking suspended material in runoff, a larger doze is needed (and a pH decline of >2 units). In higher dozes, the flocks formed, however, are fluffy and take a large volume, and need a sedimentation basin after the dozer to settle out (Fig. 6). The Ferix-dozer is

primarily meant for treating high-P waters, because the economy of chemical stripping is strongly dependant on the P concentration in runoff (Fig. 7). A study involving this type of remedy in a paddock area was reported by Närvänen et al. (Närvänen, A., Jansson, H., Uusi-Kämppä, J., Perälä, P. 2008. Phosphorus load from equine critical source areas and its reduction using ferric sulphate. Boreal Env. Res. 13, 265-274.), and more studies begin during 2010.



12.4.2008 Aaro Närvänen

Fig. 5. Schematic drawing of a ferric sulphate dozer aimed for treating ditch water.

Fig. 6. A Ferix-dozer and a settling pond in Lake Rehtijärvi area, Jokioinen. At this site, ferric sulphate was dozed during spring flood, and application of 400 kg of Ferix-3 stripped 1 kg of P from water containing 60–140 µg DRP l^{-1} (i.e., typical field runoff situation); in hot-spot ditches, a higher efficiency is obtained.

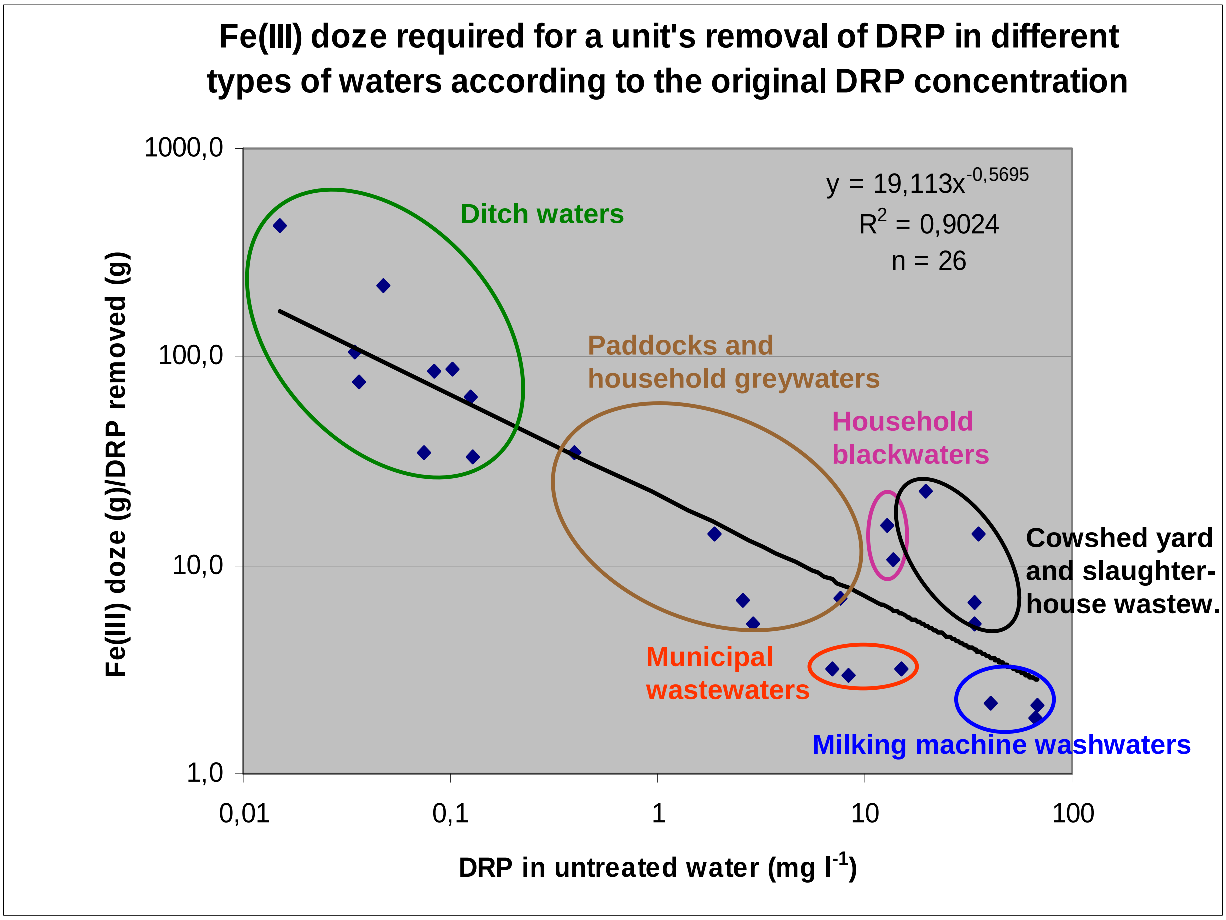
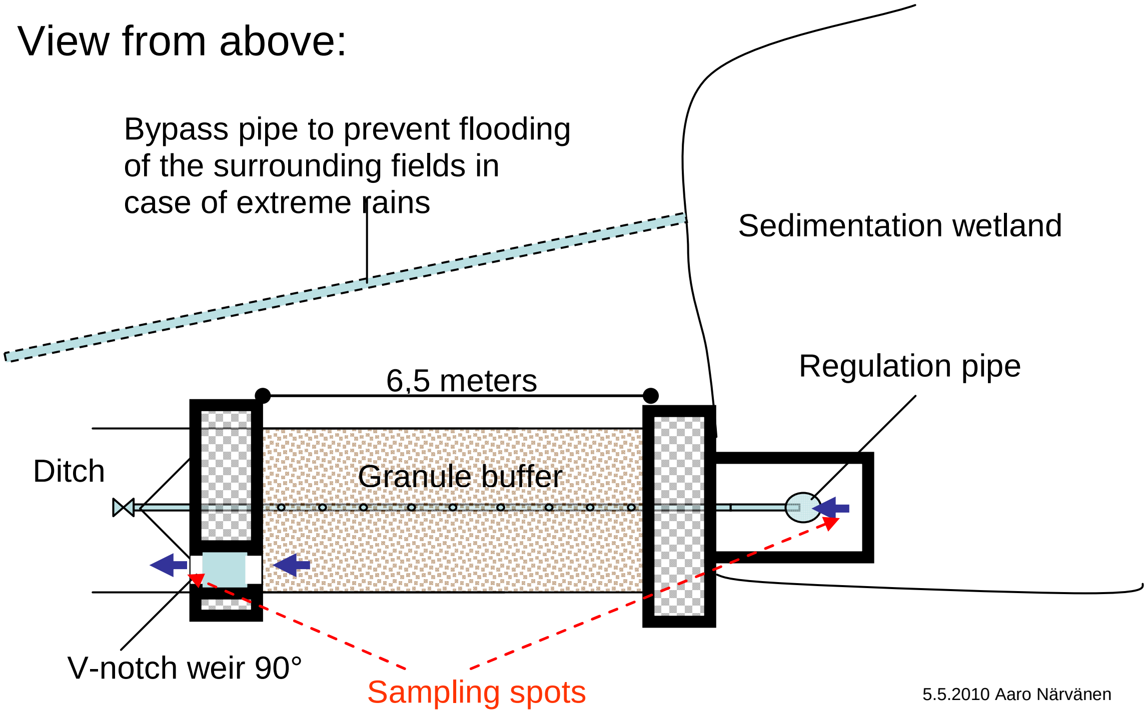


Fig. 7. Precipitating a mass unit of DRP requires less chemicals when DRP concentration in water increases. Hence, the cost of a kilogram of DRP stripped from water gets higher the longer we move downstream from a hot-spot source.

Sachtofer PR granules. Reactive permeable barrier is ideally combined with a wetland that to some degree evens out flow peaks. In the Elonkierto area, we have utilized old dam constructions and attached a perforated PVC-pipe into a pre-existing flow regulation structure (Fig. 8). The inflow into this prototype buffer is from below, through the granule mass, and out of the buffer via a v-notch weir over the lower dam. The 6.5-m area between the dam structures is filled with about 6-7 m^3 (about 9 tn) of Sachtofer PR granules, and the theoretical P retention capacity of this granule volume exceeds 60 kg of P. During the first month, it has become clear that the mass used contains too much fine material which causes preferential flow in the buffer. Also, the perforated pipe has too wide openings to distribute the flow evenly. The first test run will be done during the summer by pumping at least one 10-m^3 tank of P-spiked river water through the buffer. If the results are encouraging, the test will be repeated several times before winter. At this date, the site still lacks automatic samplers and flow monitoring devices from the in- and outlets, but they will be installed in the course of the summer 2010.

View from above:



Side view:

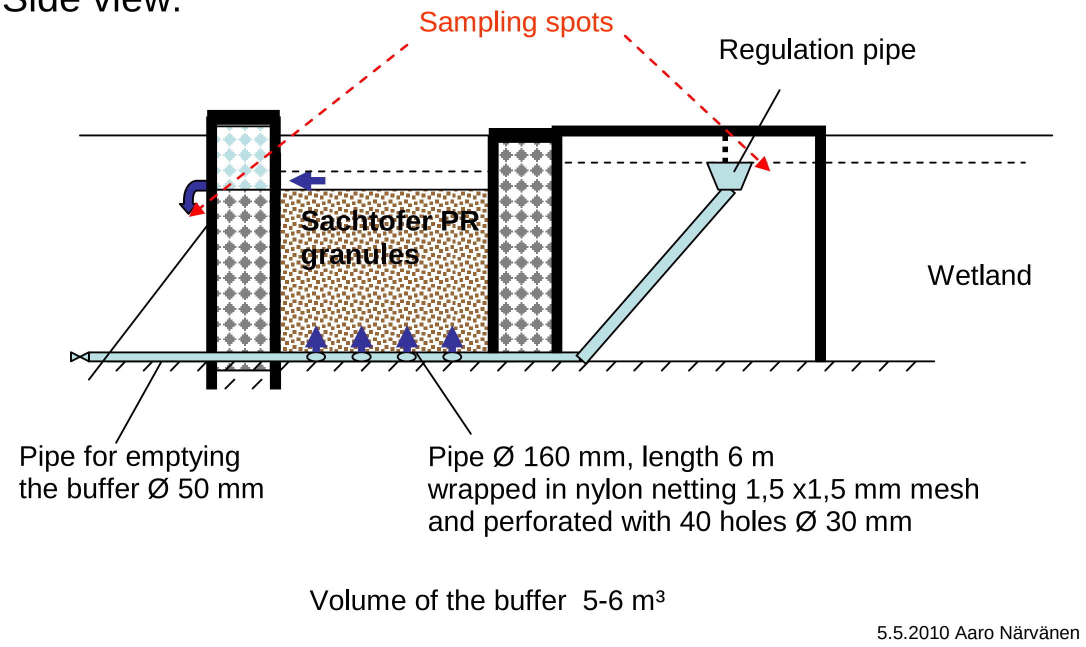


Fig. 8. Schematic pictures of the Elonkierto granule buffer, the first prototype of Sachtofer PR granules.

Tuesday, June 15, Turku. Ditch water refinery at Lake Kakskerta

Lake Kakskerta is situated in the island of Kakskerta, which is surrounded by the Archipelago Sea. The average depth of the lake is 6 m and maximum depth is 15.5 m. The area of the catchment is 7.1 km^2, 27% of which is agricultural fields. Algal blooms are a frequent late summer phenomenon. Water quality of the lake has been monitored since the 1960's and the first algal blooms were observed in the 1980's. At late 1980's restoration activities were started, including oxidation of near-bottom water and extensive fishing to decrease the sediment-disturbing fish species. The town of Turku took an active role in the restoration of the lake in 2002. For example, our excursion site, "ditch water refinery", was established in 2003 in order to curb P loading from one intensively cropped subcatchment.

Principle

The operation of the refinery is based on flocculation of soil particles and associated P, and precipitation of orthophosphate (PO_4-P) by liquid polyaluminiumchloride; the same chemical is also used in tap water purification and in some sewage treatment plants. Ditch water is pumped into a well located inside the maintenance building (Fig 9). Automatic pump doses the chemical into the water and then water is discarded into the first sedimentation pond. Sedimentation ponds need to be emptied at intervals, and sludge is spread on the surrounding fields. However, P precipitated by polyaluminiumchloride is considered to be poorly available for plants.

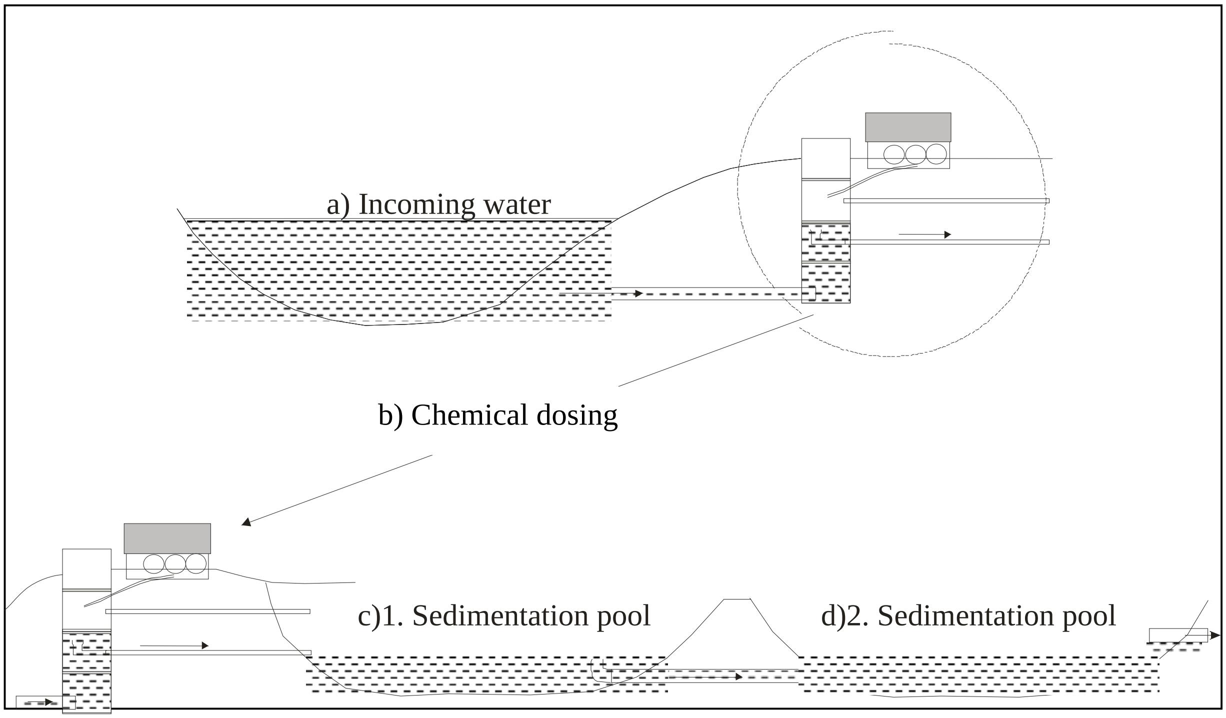


Figure 9. Schematic presentation of the ditch water treatment unit at Lake Kakskerta.

The capacity of the water pump is 6-7 l per second, which corresponds to a volume of 518–605 m^3 a day. Hence, one third of the annual flow of the catchment (158,000–210,000 m^3) can be treated. The capacity is clearly insufficient in spring and autumn. An additional pond for snowmelt water before the pump could improve the performance of the unit.

Performance

In 2009, DRP concentration of the incoming water varied between 0.020–0.110 mg l^{-1} and the concentration of TP between 0.100–0.540 mg l^{-1}. These values peaked in April, which is common for ditch waters during snowmelt. In Fig. 10, P removal is calculated as percentages. There is high variation in the results, although removal percentages above 80% for both TP and DRP were occasionally detected. These results can be considered only suggestive, because infrequent hand sampling brings about high uncertainty. The negative values may have resulted from lake water intrusion to the spot of outflow sampling. The data and full report of the water refinery will be available in near future at the web page of TEHO-project (www.ymparisto.fi/teho).

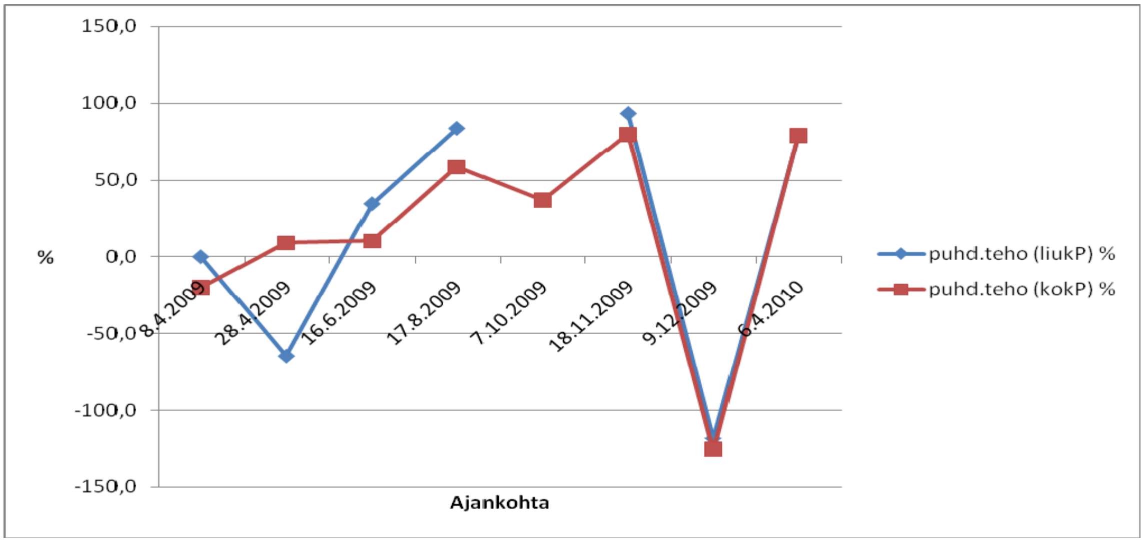


Figure 10. Phosphorus removal (%) in 2009, red line for the total P and blue line for the dissolved P.

In short, a rough estimate for overall performance of the unit for period 2003–2009 is 18 kg for TP removal and 7 kg for DRP removal. An estimate of the total costs of the treatment unit is 15,000 € (including building and maintenance). Consequently, an unrefined estimate for cost per removed kg of P would be 830 € for TP and 2140 € for DRP. Despite of uncertainties of these calculations, a unit that relies on pumps is unrealistically expensive. Thus, further studies to find an approach, which is less expensive to build and easier to maintain, are done.

Figure 11. Sedimentation pond in winter.