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Can treatment wetlands be constructed on drained peatlands for efficient purification of peat extraction runoff?

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ABSTRACT

Peat extraction for energy purposes causes major changes in the aquatic and terrestrial environment. According to national strategies for extracting peat in Finland, new peat extraction areas should be established on previously drained peatlands. On such areas it is difficult to find the natural, intact peatland required for treatment wetlands or so-called overland flow areas, which are considered the best available technology for runoff water purification. Therefore treatment wetlands must be constructed on drained peatland. It is known that drainage causes physical, biogeochemical and hydraulic changes in the peat layer, as well as changes in vegetation. It is probable that these changes affect the purification efficiency of wetland treatment systems in many ways. This study evaluated the function and characteristics of drained peatland areas for purification of peat extraction runoff water. Study sites were established on 11 drained wetlands and their purification efficiency was evaluated. Detailed measurements of peat physical properties and hydraulic conductivity, as well as studies on vegetation, were also made in the study areas. The results showed that wetlands constructed on drained peatland areas can purify peat extraction runoff. However, leaching of phosphorus (P) and iron (Fe) was observed in some areas. Leaching is influenced e.g. by pH and the soil P pool. The chemical oxygen demand was also observed to increase in runoff water from the wetland. The results indicated that low (Fe + aluminium (Al) + manganese (Mn))/P ratio (≤25) and quite high P content (>1200 mg/kg) in the surface peat characterised those areas where P leaching was observed. The presence of a dense tree stand in a drained peatland area also seemed to indicate release of nutrients from the area after its rewetting and use as a treatment wetland. Thus, potential nutrient release from a drained peatland area intended for use as a treatment wetland can be assessed by studying the characteristics of the peatland area, especially the peat mineral content, and the vegetation, especially tree stand density in the area. Using the findings obtained, a conceptual decision tree was drawn up in order to help to establish and design wetlands in previously drained peatland areas.

1. Introduction

Wetlands are widely used globally as a purification step in wastewater treatment, for example in agricultural (Dunne et al., 2005) and municipal systems (Kadlec and Wallace, 2009). Treatment wetlands are designed to filter and treat runoff water pollutants based on sedimentation, physical filtration, geochemical processes and aerobic and anaerobic biological processes in the wetlands (Kadlec and Wallace, 2009). Generally, numerous characteristics affect purification, such as residence time (Wörman and Kronnäs, 2005), soil properties (Heikkinen et al., 1995; Kadlec and Knight, 1996; Liikanen et al., 2004; Pant and Reddy, 2003), biological factors such as microbes and plants (Henze et al., 2002; Huttunen et al., 1996), climate (Kadlec, 1999; Kuschk et al., 2003; Werker et al., 2002), redox dynamics (Niedermeier and Robinson, 2007), pH (Grybos et al., 2009; Kadlec and Knight, 1996) and hydraulic load (Braskerud, 2002; Heikkinen et al., 2002).

In Finland, treatment wetland systems are commonly constructed on peatlands due to their wide availability and their suitability for treating and polishing different types of wastewater. Due to the cool, humid climate and flat topography, peatland covers about one-third of the land area in Finland. Peat-based wetlands are used to treat runoff from peat extraction areas (Heikkinen et al., 1995; Ronkanen and Kløve, 2009) and in peatland forestry (Nieminen et al., 2005; Silvan et al., 2004), and also to polish municipal wastewater (Ronkanen and Kløve, 2007) or mining effluents (Närhi et al., 2012; Päkkilä, 2008). In peat extraction, treatment wetlands are mainly called overland flow areas (OFAs, see Fig. 1) and they are established on undisturbed peatlands. According to guidelines set by the Ministry of the Environment (2013), wetland slope (recommendation 1%), treatment wetland area of the catchment area (recommendation > 3.8%), average

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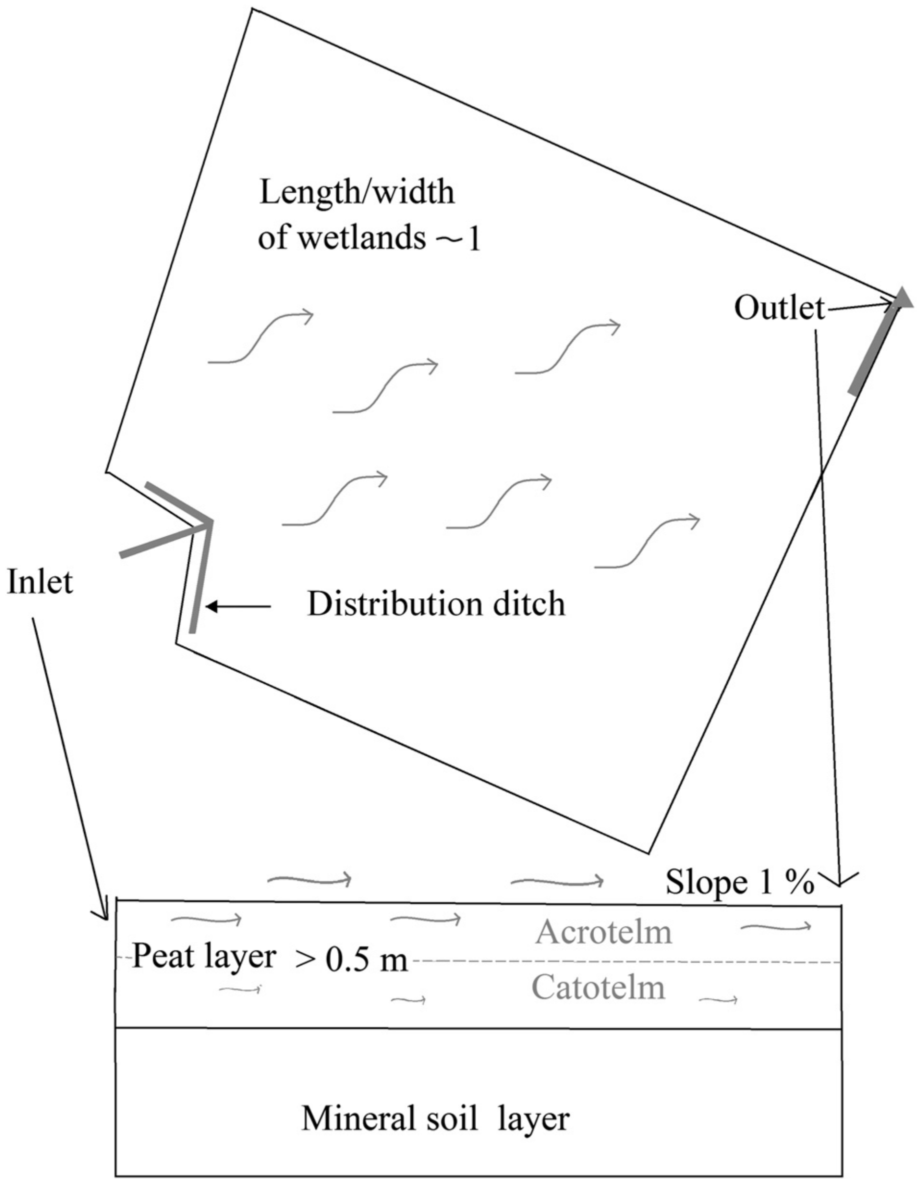

Fig. 1. Example of a water treatment wetland.

peat thickness (recommendation > 0.5 m) and average degree of humification of surface peat (recommendation H1–H3) are parameters which should be analysed in OFAs, as they can affect their purification efficiency. OFAs are considered to belong within best available techniques (BAT) in purifying runoff water from peat extraction sites (Heikkinen et al., 2009). However, the current national areal planning strategy (Ministry of the Environment, 2007) directs the implementation of new peat extraction sites to previously drained areas. In these peatland areas it is difficult to find the natural, intact peatland surface areas needed for OFA wetland treatment systems (Ihme, 1994; Ihme et al., 1991), and treatment wetlands must thus be constructed on drained peatland areas. Therefore, dozens of treatment wetlands have already been established on drained peatland areas without any knowledge of their functionality or design parameters.

It is well known that peatland drainage changes the peat's physical properties (Burke, 1978; Holden et al., 2004; Vasander et al., 2003), such as porosity, hydraulic conductivity, degree of humification, water content and geochemical properties. Water pathways in peatlands are altered by lowering the groundwater level and providing more rapid outflow for surface runoff and rainfall (Holden, 2009). In treatment wetland areas, old drainage ditches can function as cut-off channels, thus reducing retention time and impairing purification results. However, there is a wide range of variation in soil physical and hydraulic properties and in vegetation cover in drained peatlands, which is often dependent on peat type and local characteristics (Kløve, 2000). Establishment of a treatment wetland on a drained peatland area involves rewetting, which promotes further changes in soil, vegetation and hydraulic features of the area (Haapalehto et al., 2011). Rewetting also changes the aerobic and anaerobic conditions in peat layers. This may cause leaching of nutrients and geochemical elements, as has been noted at peatland restoration sites (Koskinen et al., 2011; Vasander et al., 2003). All of these issues need to be clarified before treatment wetlands can safely be established on drained peatland areas. At present, little or no information is available on the major factors and mechanisms influencing purification processes in treatment wetlands established on drained peatland areas.

From a water treatment point of view, it is important for treatment wetlands to retain nutrients (P and nitrogen (N)) and suspended solids (SS) present in runoff water. Removal of P from runoff water is perhaps one of larger challenges in treatment wetlands established on drained peatland areas compared with OFAs. The purification results for P in OFAs or other types of treatment wetlands depend on different