Extended abstract No. 96

DIC AND DOC IN THREE MIRES REPRESENTING DIFFERENT PEATLAND DEVELOPMENT STAGES IN A CALCAREOUS AREA OF CENTRAL SWEDEN.

Löfgren, A, EcoAnalytica, Haeffnersvägen 23, 129 38 Hägersten, Sweden, +46704062932, ecoanalytica@gmail.com.

Saetre, P, Swedish Nuclear Fuel and Waste management Company (SKB).

SUMMARY

In this study we examined the variation in DIC and DOC concentration during mire ontogeny, by sampling three mires at a coastal area with land upheaval, a flat topography and calcareous soil in central Sweden (site Forsmark). Water samples were collected from all three mires at two different depths in the anoxic layer of the mires, by extracting water from peat obtained with a peat corer. DIC concentrations where related to the age and the depth of the mires, with the lowest concentrations in the oldest mire and in the shallow samples. DIC concentrations were also positively related to the electrolytical conductivity of the pore water within and between the mires, reflecting the influence of groundwater rich in calcium cations. DOC concentrations varied to a less extent, but were highest in the oldest mire.

KEY WORDS: Mire, DIC, DOC, rich fen

INTRODUCTION

The calcareous content of the Quaternary deposits around the Forsmark site is typical for the north-eastern part of Uppland region in central Sweden. The deposits originate from the latest glacial period and are more evident closer to the coast of the Baltic Sea, where the more recently uplifted areas have been less exposed to weathering. The lime content in the regolith is manifested as a high pH in lakes and mires, where lakes are classified as oligotrophic hard water lakes and mires are dominated by rich or extreme rich fens. This has implications for the components of the carbonate system; dissolved CO_2, HCO_3^- and CO_3^{2-}, which together constitute the potential pool of dissolved inorganic carbon in the water. For mires with pH less than 6, H_2CO_3 is the dominating component, and when pH is between 6.5 and 10, HCO_3^- is the dominating component.

In the safety assessment SR-Site (nuclear power waste repository), the potential exposure of radionuclides to humans and non-human biota was estimated using a model that is dependent on a large number of parameters (SKB 2010). For parameters describing pools and fluxes of dissolved carbon in rich fens, data were few or non-existing, both from the site and in literature. In the forthcoming safety assessment for a repository containing waste of low or middle activity, the radionuclide C-14 will become important in terms of exposure in the case of a potential release of radionuclides from the repository. It was therefore adequate to increase the knowledge of dissolved inorganic carbon (DIC) of mires in the Forsmark region. At the same time, estimates of concentrations of dissolved organic carbon (DOC) were included in the sampling campaign. It was also considered relevant to put differences in concentrations into a mire developmental perspective.

This document describes the first attempt to estimate concentrations of DIC and DOC from three representative mires around Forsmark site and relate these concentrations to depth and age of the mires.

MATERIALS AND METHODS

The three mires represent a potential peatland development gradient, where the first mire Labboträsk I surrounds a small lake water surface, the second mire Labboträsk II lacks a lake water surface. They are both classified as rich fens. The oldest fen, Stenrösmossen, has characteristics of both a fen and more bog-like environments. This order of development is also supported by their location in relation to the current sea level. They were investigated during the vegetation period 2010 (see Löfgren (2011) for a detailed description of methods and results). DOC, DIC and additional chemical parameters were sampled during 26th to 27th of August and one additional sampling was made 22th of October at Stenrösmossen.

A peat corer with the diameter of 1 dm was used to collect a peat profile approximately down to 0.7 m. The samples (Table 1) were taken below the oxic zone and the depth 0.35 m was identified to be located in the anoxic zone in all mires. Immediately after the peat profile was brought to the surface, water was pressed from a ten cm peat sample. Water was squeezed from the peat sample and collected in bottles. At some sampling points, an additional deeper core was removed in close vicinity to the first shallow core. The same procedure was used for taking the deeper water sample as for the shallow water sample.

Table 1. Number of water samples distributed among mires, depth, season and additional samples. All samples were collected during late August except for those marked with *, which were collected in late October.

Mire	Shallow sample	Deep sample	Additional samples
Labboträsk I	5	2	2 (lake water)
Labboträsk II	5	2	-
Stenrösmossen	6+6*	2+2*	1* (Outlet)
Summa	**24**	**8**	**3**

RESULTS AND DISCUSSION

Concentrations of DIC

The estimated DIC concentrations in the samples from the three fens ranged between 2 and 75 mg L^{-1}. A similar range was found by Nilsson and Bohlin (1993) who measured DIC in 12 mires in northern Sweden (between 12 and 78 mg L^{-1} of individual samples) during August and September. That study was considered to represent a large range of origins, water regimes, depths and nutrient status to be found in the anoxic zone of mire ecosystems in the northern boreal zone. These mires did, however, only represent mires with relatively low pH where all inorganic carbon occurs as CO_2, which is not the case for the mires in the Forsmark region, where approximately 20 to 50% of the inorganic carbon occurs as HCO_3^- in the interval between pH 5.7 and 6.4. The mean DIC concentration for 9 of the mires in northern Sweden was 33 mg L^{-1} (Nilsson and Bohlin 1993). These were shallow samples from between 0.3 and 1.2 m and concentrations comparable to those found in the rich fen Labbotträsk II (32 mg L^{-1}).

The distribution of DIC estimates among the mires is shown in Figure 1. DIC concentrations increase from the oldest mire to the youngest. A higher DIC concentration could indicate a higher inflow of carbonate-enriched groundwater into the mire. Such patterns has been correlated to concentrations of major cations associated to groundwater, i.e. Ca^{+2} and Mg^{+2} (Sjörs and Gunnarsson 2002, Tahvanainen *et al.* 2003). A relevant proxy for these cations is the electrolytical conductivity (i.e. Sjörs and Gunnarsson 2002), and the decreasing conductivity with increasing age of the three mires support the hypothesis of a partly groundwater-induced pattern. Another interpretation of patterns in DIC and conductivity among samples could be that the inflowing groundwater is heavily depleted in DIC and Ca^{+2} in higher locations due to long-term leaching.

Concentrations of DOC

The measurements of DOC in the three mires ranged between 25 and 84 mg L^{-1} (and one extreme sample with 161 mg L^{-1} representing a drained part of the Stenrösmossen with *Sphagnum* peat). Tahvanainen (2004) investigated the water-saturated oxic layer of 36 mires in Finland, classified according to a poor – rich gradient and found a range in DOC concentrations between 5 and 85 mg L^{-1}. The DOC concentration was higher in the older fen Stenrösmossen than in the two other fens. Tahvanainen (2004) found a pattern in DOC concentration in the oxic layer connected to the poor – rich fen categorization (pH) when mires with similar geochemical settings (granitoid bedrock/metabasite) were compared. High DOC values were connected to low pH values. This pattern suggests that the DOC concentration could be related to the peat development stage of the mire, where older mires have more stagnant hydrological conditions and are more affected by autochthonous processes, such as heterotrophic respiration.

DIC and DOC concentrations within one mire

In Stenrösmossen there is an increasing trend in the DIC concentration as a function of the distance to the outlet from the mire (Fig. 2). DOC showed the opposite trend. This pattern could suggest an effect of increasing water movement, but the distance is confounded with differences in the vegetation. The samples with the lowest DIC concentrations and the highest DOC concentrations were from the oldest part of Stenrösmossen dominated by late successional species, such as *Pinus sylvestris*, deep *Sphagnum* peat and hydrologically more stagnant conditions. The opposing trends may suggest that a large part of DIC and DOC in the anoxic layer have different origin, where DIC mainly is transported with the water entering the mire, whereas DOC is produced locally within the wetland.

The small data set from the oldest fen Stenrösmossen suggests that the DIC concentrations in the anoxic layer seem to be quite stable during the autumn compared to the summer (Fig. 2). Several factors may contribute to this pattern. The overall low DIC concentration in this mire suggests a relatively small input of carbonate-enriched groundwater. From the work with peat corings on the three mires it was possible to infer that water mobility was larger within the two younger mires, due to differences in the presence and density of peat with depth.

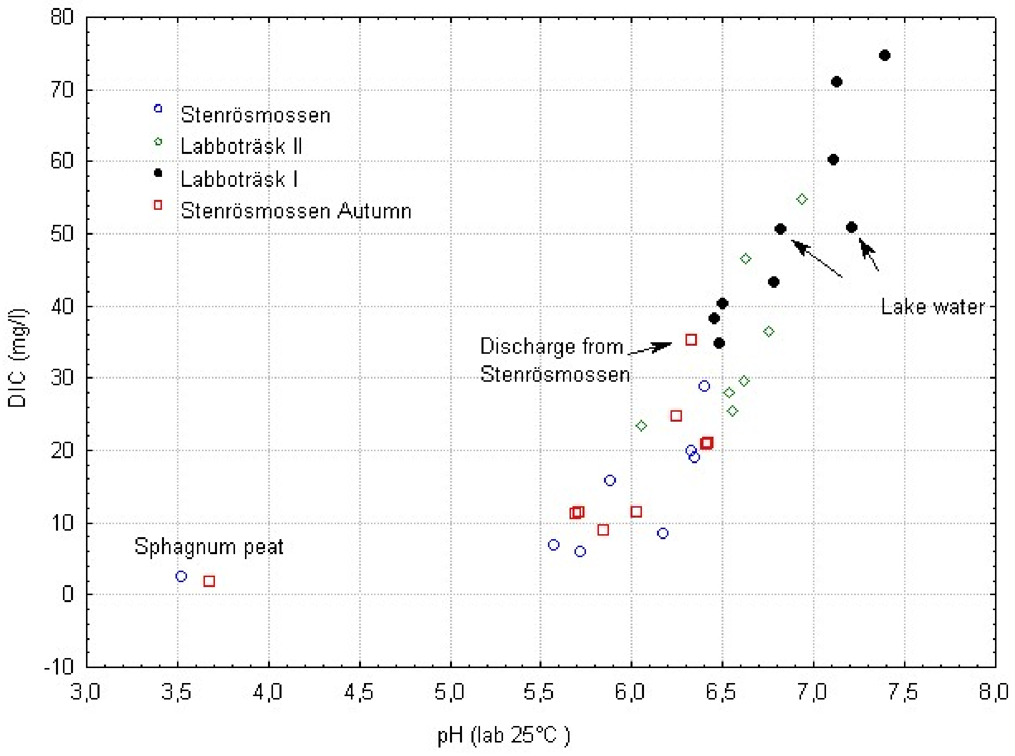

Figure 1. The relationship between pH and DIC in the developmental gradient from the oldest mire on the left to the youngest on the right including both shallow and deep concentration estimates. Some additional samples describing outlet and lake water is included for comparison.

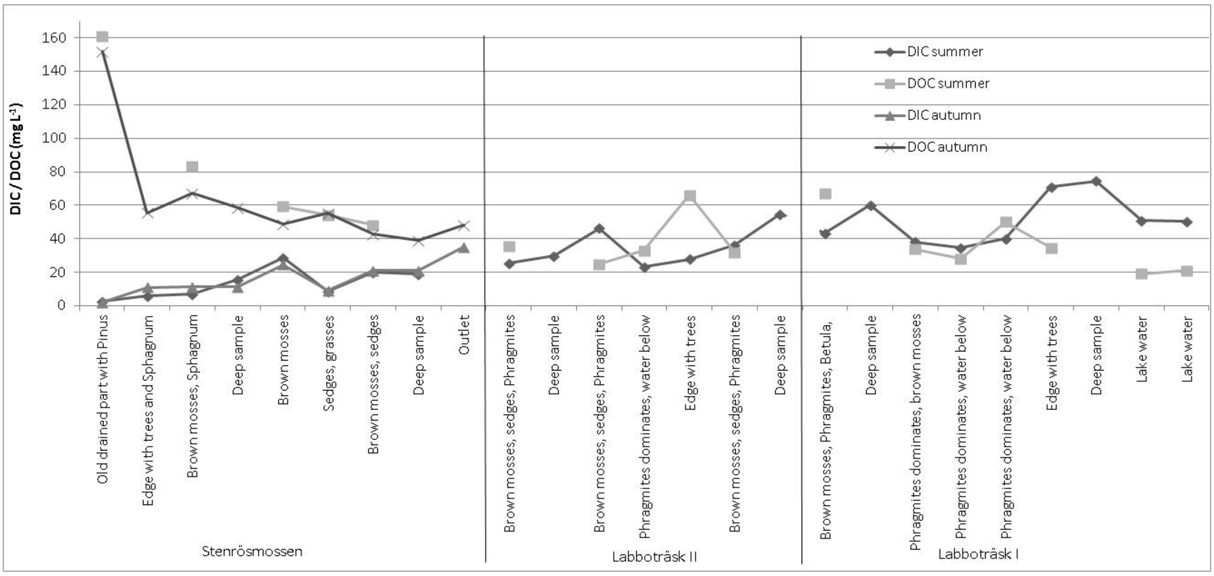

Figure 2. Pattern of DIC and DOC concentrations among vegetation types, deep and shallow cores, and location within the mire, where samples have been arranged according to their distance to the outlet from the mire. Stenrösmossen is the oldest highest located fen and is not connected to the other two fens. Labboträsk I and II are connected through a pipe under a road. The text “water below” on the horizontal axis indicates that there is a free water volume beneath the *Phragmites* root mat.

CONCLUSION

The present study, although based on few replicates, suggests that DIC concentrations are similar to estimates from mires in northern Sweden with lower pH. Moreover, it also suggests differences in DIC concentrations among mires of different ages in an area like the Forsmark site, characterized by calcite-rich deposits and high groundwater pH. Differences also seem valid for DOC concentrations, but less for younger fens. DIC measured in the anoxic layer is produced during decomposition in the summer, but is added with increased water influx enriched by the carbonate-rich till in spring and autumn. DOC on the other hand is mainly produced during heterotrophic respiration.

Both DIC and DOC seem to be related to pH, however, in opposite ways. pH associated to the poor/rich index of mires seems to describe the peat development of mires in site Forsmark and it would be possible to use pH as a proxy for mire development in this area where land upheaval occurs. DIC and DOC also seem to be related to the water transport within the wetland and between wetlands, suggesting that a considerable part of DIC originates from groundwater.

ACKNOWLEDGEMENT

The field work was made together with Micke Borgiel (Sveriges Vattenekologer AB). Anders Sjösten (Stockholm University) made the analysis of DIC and DOC. Cecilia Berg (Geosigma) made all other lab analysis. Gustav Sohlenius (SGU) and Mats Tröjbom (Mats Tröjbom Konsult AB) contributed in discussions and by commenting on earlier versions of this text. Björn Söderbäck (SKB – Swedish Nuclear Fuel and Waste management Co.) contributed with a detailed review of the manuscript. This study was financed by SKB.

REFERENCES

Löfgren, A. (2011). Dissolved inorganic carbon and organic carbon in mires of Forsmark - A pilot study. SKB P-11-23, Svensk Kärnbränslehantering AB. (Download from www.skb.se)

Nilsson, M. and Bolin, E. (1993). Methane and carbon dioxide concentrations in bogs and fens – with special reference to the effects of the botanical composition of the peat. Journal of *Ecology* 81, 615-625.

Sjörs, H. and Gunnarsson, U. (2002). Calcium and pH in north and central Swedish mire waters. *Journal of Ecology* 90, 650-657.

SKB, (2010). Biosphere analyses for the safety assessment SR-Site – synthesis and summary of results. SKB TR-10-09, Svensk Kärnbränslehantering AB. (Download from www.skb.se)

Tahvanainen, T. (2004). Water chemistry of mires in relation to the poor-rich vegetation gradient and contrasting geochemical zones of the north-eastern Fennoscandian shield. *Foila Geobotanica* 39, 353-369.

Tahvanainen, T., Sallantaus, T. and Heikkilä, R. (2003). Seasonal variation of water chemical gradients in three boreal fens. *Annales Botanici Fennici* 40, 345-355.