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Dependence of Total Mercury in Superficial Peat With Nutrient Status: Implications for Stability of Peat as an Archive of Hg Deposition

Totalkviksilver i ytlig torv i relation till näringsstatus:
Implikationer av torvens stabilitet för dess roll
som ett arkiv för upptag av Hg

Jacob Smeds

INSTITUTIONEN FÖR
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Abstract

Dependence of Total Mercury in Superficial Peat With Nutrient Status: Implications for Stability of Peat as an Archive of Hg Deposition

Jacob Smeds

Although Mercury (Hg) has decreased considerably in the atmosphere during recent decades, this potent neurotoxin still constitutes a threat to ecosystems globally through the Hg stored in soils. The mitigation of the risks related to this legacy Hg was a reason to implement the Minamata Convention. Subsequent work under the convention is dependent on assessments of the Hg stored in the environment. A way of doing this is to study environmental archives of atmospheric deposition such as ice cores, lake sediments, and peatlands. A previous study along a chronosequence of mires along the northern coast of Sweden showed Hg content differing by a factor of 2 and correlating strongly with mire age. This was hypothesized to indicate that differences in minerogenic water supply along the chronosequence influenced the stability of Hg after deposition from the atmosphere to the mire surface. Declining access of minerogenic elements with increasing peatland age results in a less nutrient demanding plant species composition as well as decreasing access to microbial electron acceptors. But that study looked at just one 10 cm layer at a depth with peat ca 50 years old. Here we present a more rigorous test of that hypothesis by presenting the total amount and vertical pattern of Hg accumulation during the last 200 years in the superficial peat along that peatland chronosequence.

Eleven peatlands along the northern coast of Sweden near Umeå were sampled. This is an area where isostatic rebound continues to raise the land above the sea level. Triplicate peat cores were collected from both lawns and hummocks, when present. A total of 30 peat cores, each 50 cm deep, were collected and frozen immediately. The cores were then sliced into 2 cm layers, and each slice was analysed for total Hg.

Our results suggest that there is no difference in total Hg (THg) between young and old mires at the superficial 50 cm peat depth, considering the THg concentration. The total amount of Hg (on a mass basis) is however greater in old mires than in young mires. This is driven by the fact that more peat is accumulated at old mires than in young mires at 0-50 cm. A crucial point in our chronosequence data is the assumption that the superficial 50 cm of peat at the mires are of the same age, regardless of mire age. The peat cores were however not dated in this project, leaving the caveat that the superficial peat might not be of the same age. The net deposition of Hg is greater in the superficial 50 cm at old mires than at young mires if the peat cores are of the same age. If the age of the peat cores differs (i.e., the peat at 50 cm depth is older at old mires than at young mires), it is likely that the net Hg deposition is similar between young and old mires for a given time interval.

Keywords: Peat, mercury, paleoarchive, chronosequence

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Populärvetenskaplig sammanfattning

Totalkvicksilver i ytlig torv i relation till näringsstatus: Implikationer av torvens stabilitet för dess roll som ett arkiv för upptag av Hg

Jacob Smeds

Efter att höga halter kvicksilver uppmättes i atmosfären under 1900-talets mitt har halten kvicksilver minskat i luften. En viss mängd av den kvicksilver som tidigare fanns i atmosfären är nu dock uppsamlad i jordmånen, vilket hotar ekosystem på land, samt sjöar och vattendrag. Faktum är att majoriteten av Sveriges ca. 100 000 sjöar har fisk vars halt av detta nervgift överstiger EU:s rekommendationer för mänsklig konsumering. För att minska kvicksilvrets skadeverkningar, och för att öka medvetenheten kring dess risker, implementerades Minamatakonventionen av Förenta Nationerna 2013. En viktig del av denna konvention är just att kartlägga jordmåner som källor till kvicksilver i sjöar och vattendrag. En jordart med generellt höga kvicksilvernivåer är torv. Fokus för detta projekt är därför kvicksilver i myrar (torvmarker), och hur den totala mängden kvicksilver vid myrens yta (0-50 cm djup) varierar med myrars ålder. Myrar är också en källa för den giftigaste formen av kvicksilver: metylkvicksilver. Denna form av kvicksilver är bunden till ett protein, vilket ökar risken för biologiskt upptag av kvicksilver hos människor och djur.

I en tidigare studie vid samma myrar som kommer undersökas i detta projekt var andelen metylkvicksilver (av den totala mängden kvicksilver) vara högre i unga myrar (yngre än 1 000 år) än i gamla myrar (äldre än 2 000 år). Dock var den totala mängden kvicksilver högre i gamla myrar än i unga myrar (0-10 cm under grundvattenytan). Detta ledde till hypotesen att samma process som metylerar kvicksilver också kan leda till kvicksilverremission. Vidare konstaterade den tidigare studien att myrar med relativt höga halter metylkvicksilver var näringsrika (unga myrar), till skillnad från (gamla) näringsfattiga myrar där metylkvicksilver utgjorde låg en låg andel av den totala mängden kvicksilver.

I den tidigare studien insamlades dock bara torvprover ned till ett djup av 10 cm från grundvattenytan. I detta projekt undersöks istället torv till ett djup av 50 cm från myrens yta. Koncentrationen totalkvicksilver vid 0-50 cm påvisade inte någon skillnad i kvicksilverhalt mellan unga och gamla myrar. Å andra sidan är den totala mängden kvicksilver större i gamla än i unga myrar, beroende att mer torv är ackumulerad vid myrens yta (0-50 cm) i gamla myrar.

Nyckelord: Torv, kvicksilver, palaeoarkiv, kronosekvens

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1. Introduction

Mercury (Hg) is a potent neurotoxin, constituting a threat in aquatic systems where Hg bioaccumulates in the food chain (Ward et al. 2010). In fact, almost all of Sweden's 100,000 lakes have fish with Hg levels higher than what is recommended for human consumption by the EU (Åkerblom et al. 2014). Problems related to Hg have led to the Minamata Convention formed by the United Nations, with a goal of increasing awareness of Hg-exposure and to mitigate anthropogenic emissions (Kessler 2013). Anthropogenic emissions of Hg mainly include non-ferrous metallurgy, coal combustion, and chlorine production (Biester et al. 2006; Zuna et al. 2012; Obrist et al. 2018).

Though the current concentration of Hg in the atmosphere still exceeds the concentration prior to anthropogenic influence, the last decades have seen a decrease in atmospheric Hg levels (Zhang et al. 2016). Past high Hg deposition has however led to Hg enrichment in soils, often referred to as legacy Hg. This Hg still constitutes an active threat, due to the risk of leakage to downstream ecosystems or re-emission to the atmosphere (Obrist et al. 2017; Osterwalder et al. 2017). An important part of future Hg research is therefore to assess the amount of Hg stored in soils. This project will, among other things, assess the amount of Hg stored in organic soils (i.e., peat), with a focus on Hg retention in relation to soil nutrient status.

The gradual accumulation of organic matter in peatlands, to which Hg has a strong affinity, (Skylberg et al. 2000) also offers a chronological archive of Hg deposition (Biester et al. 2002; Bindler et al. 2004). Though peatlands are widely utilized as palaeoclimatological archives (Benoit et al. 1998; Biester et al. 2007; Talbot et al. 2017), Hg retention in peat is not fully understood. As previously mentioned, Hg can for example be re-emitted to the atmosphere after deposition or transported to downstream ecosystems (Osterwalder et al. 2017; Haynes et al. 2017, 2019). At a peatland chronosequence near Umeå, Sweden, a study suggested that the mobility of Hg in peatlands was increased with Hg methylation, due to lateral runoff or re-emission (likely the latter) (Wang et al. 2020). The basis for this conclusion was that the proportion of methylmercury (MeHg) was correlated with total Hg (THg). The %MeHg (of THg) were particularly high at young nutrient rich mires (the words *mire*, and *peatland* are used synonymously). It was also shown that the nutrient rich mires contained less THg, suggesting that the same process that methylates Hg promotes Hg mobility. Based on this, the authors of that study (Wang et al. 2020) (Fig. 1) suggested looking more closely at THg content in relation to methylation potential, which correlates with peatland nutrient status and mire age.

Fig. 1. Peatland age and the relationship between nutrient status, THg, and MeHg. Modified from Hu et al. (2019).

That chronosequence used by Wang et al. (2020) was created by postglacial uplift along the coast of Scandinavia which created a chronosequence of peatlands close to Umeå, northern Sweden. Young mires are hence found close to the coast, with gradually older mires further inland. The sediment underlying the mires are a potential source of some nutrients, and the separation to the nutrient source increases as a mire ages and the thickness of the peat layer increases. Thus, the chronosequence also represents a gradient in nutrient status. Young peatlands are more nutrient rich and old peatlands more nutrient poor.

It is important to emphasise that the previous study by Wang et al. (2020) found an inverse relationship between MeHg and THg along this peatland nutrient gradient, which led to the hypothesis that mire catchment geochemistry in general and nutrient availability in particular controls both MeHg production and Hg mobility. The study was however only conducted on the 10 cm layer of peat just below the average growing season groundwater table (GWT) (established at each mire by Wang et al. (2020)). There was also a key assumption in that study, namely that this superficial peat is of the same age regardless of mire age.

Dating of the surface peat profiles will be key to confirming this assumption about equal age, but a more complete analysis of the accumulation in the peat profile would also allow for a fuller investigation of how Hg accumulates. In this study, we will therefore quantify the profile of THg content in the 50 cm below the mire surface in 10 of the 15 mires sampled by Wang et al. (2020) (as well as at another nearby, somewhat older Degerö Stormyr which has been the subject of earlier studies on MeHg (e.g. Bergman et al. 2012, Åkerblom et al. 2013). These upper 50 cm are expected to cover an age range back to ca 1800. This period is interesting because it covers the industrialized period during which Hg in the atmosphere rose sharply starting from the industrial revolution until ca 1980, before falling back in recent decades (Streets et al. 2017; EEA 2018). Since some of these mires have both hummocks and lawns, differing significantly in growing season average water table depths, the study will look also look separately at the Hg profiles in both mire microtopographical units.

Based on the THg depth profiles in the superficial 50 cm of the mire, this study examines the hypothesis that MeHg makes Hg more susceptible to mobilisation with three research questions:

[RQ1] *Do the chronosequence mires accumulate Hg from the atmosphere into the surface peat at similar concentrations?*

[RQ2] *Is the distribution of the Hg in the top 50 cm similar along the chronosequence?*

[RQ3] *Are the chronosequence mires similar in their retention of Hg?*

2. Methods

2.1. Site description

The study site is located close to the coast of the Baltic Sea near Umeå, Sweden (63°53'N 20°42'E). The peatlands studied herein are created by the isostatic rebound from the last glacial maximum in Scandinavia. Older peatlands are therefore found as the elevation and the distance from the coast increases. The peatlands are all located within a distance of 10 km, thus the mire catchments have similar underlying soil and bedrock mineralogy and also exposed to similar climate and atmospheric Hg concentration (Hu et al. 2019; Wang et al. 2020). The chronosequence peatlands are divided into three age classes: young (< 1000 years old), intermediate (1000-2000 y/o), and old (> 2000 y/o) (Fig. 2).

Fig. 2. The peatland chronosequence with a classification of young, intermediate, and old mires. The number close to the markers are the peatland labels (Wang et al. 2020). Only 10 of the 15 mires are sampled in this project (mire 16, 18, 24, 33, and 43 were not sampled). The mire Degerö Stormyr 50 km northwest of the chronosequence was also sampled (64°11'N, 19°33'E). (Figure adapted from Wang et al. 2020)

The peatland chronosequence also represents a gradient in surface peat nutrient availability, i.e. conditions having a major influence on plant- and microbial community composition, from young mesotrophic minerogenic mires to older oligotrophic minerogenic or even ombrogenic mires. The minerogenic peatlands are fed by nutrients from the underlying mineral soils, or from the surrounding watershed. As the peat accumulates, the plants at the mire surface will become disconnected from the underlying mineral soils. The amount of nutrients in the surrounding catchment also decreases by time

due to continuous weathering and leaching by precipitation. Both processes combine to result in a long-term oligotrophication of the peatlands.

Fig. 3. further defines the biogeochemistry and vegetation of the 15 chronosequence mires from Wang et al. (2020) in relation to mire age (10 of these mires are included in this study). The defining characteristics for the different age classes are nutrient availability, carbon (C) content, vegetation, pH, and elevation. These data are from the 10 cm below the GWT. It is assumed that these peat layers from different mires have similar ages, regardless of the mire age. The difference between the mires stems mainly from the separation from the underlying nutrient source (Wang et al. 2020).

Fig. 3. PCA scores (a) and loadings (b) from Wang et al. (2020). The PCA scores represent young, intermediate, and old mires (blue triangles, green squares, and pink dots respectively) from the lawn sites. The loadings reflect biogeochemical parameters and vegetation type of the chronosequence mires. Relative high and low loadings particularly characterises the mires.

Small hummocks are scattered over some mires (~25 cm over the base level). These microtopographical elevation maxima are commonly referred to as *hummocks*, while the mire base level is referred to as *lawn* (or *hollow*) (Norton et al. 1997). A difference between hummocks and lawns is the distance to the GWT. Typical distance to the GWT for hummocks is 25-50 cm, and the lawn is located close to the GWT (typically 5-15 cm). The distance to the GWT have fundamental implications for the vegetation and biogeochemistry at the specific point on the mire. Hummocks and lawns are therefore presented separately in this report.

The mires are Sphagnum dominated, though sedges are more common at the young mires and ericaceous shrubs more common at the old mires (Wang et al. 2020). A full list of mire vegetation at the lawn microtopography is found in the SI (Table S2). Hummocks are also sphagnum dominated, with occurrence of ericaceous shrubs.

The mean annual temperature in the region is 1.8 °C, with a mean of -9.5 °C in January and +14.7 °C in July (measured 1981-2010 at Svartberget Field Research Station; 64°14'N, 19°46'E. The climate is cold temperate humid with snow-covered winters (Laudon et al. 2013).

2.2. Sampling and processing of the peat cores

The 50 cm peat cores were collected close to the centre of the mire using a circular stainless-steel corer and 15.1 ø cm PVC plastic tubes (Fig. S1). The corer was used for pre-drilling the surface peat to ease the insertion of plastic tubes used to extract the peat core. The corer and tubes were always cleaned from previous usage. The corers and the tubes were also used for drilling at the site as an extra cleaning procedure before collection of the peat cores. Watertight caps were used to seal the cores from water leakage after sampling. The cores were held upright and transported to the lab within 4 hours after sampling.

The samples were stored in a -18 °C freezer before being sliced into 2 cm discs. The slicing was done in a freezing room (also -18 °C) using a bandsaw with a stainless-steel blade. The thickness of the discs was rigorously controlled, and the weight noted after slicing to enable calculation of the density with the known volume of the discs, i.e. bulk density. The sliced samples were stored in -18 °C in air-tight plastic bags before drying.

The samples were air-dried at 60 °C for 96 h (the maximum time required to reach constant weight). The samples were placed in a desiccator immediately after drying to avoid absorption of moisture before the dry weights were noted.

Since Hg is volatile, there is a risk of Hg evasion when heated (Roos-Barraclough et al. 2002). A common method used to limit Hg loss during drying is therefore freeze-drying. Though even freeze-drying is an imperfect method for drying of peat samples (Martinez-Cortizas et al. 1999), a sub-set of samples were freeze-dried (for ~1 week) to evaluate whether there were losses of Hg created by air-drying relative to freeze-drying (see *Freeze-dried vs. air-dried Hg* in the results section).

The samples were pre-homogenised to enable subsampling for milling. An IKA Tube Mill Control (IKA, Staufen, Germany) with single use milling chambers were then used to grind the samples to a fine powder. Bulky roots and wood were removed prior to milling of the samples.

The THg in the peat samples were analysed using a Milestone Direct Mercury Analyzer (DMA) 80 (Milestone, Shelton, CT, USA). A replicate of each sample was analysed every fifth sample along with a reference sample to cross-validate the analytical precision. The results were always within $\pm 15\%$ of the reference samples, with an average underestimation of $3.2 \pm 5.8\%$ (s.d.) of the measured THg relative to the reference material (table 1) (NIST 1515 – Apple Leaves Standard Reference Material®, ERMCD-281 – Rye Grass ERM® certified Reference Material, ERM-CC141 – Loam Soil ERM® certified Reference Material). The measured THg concentration had an average *absolute* deviation from the reference sample of $5.6 \pm 3.6\%$ (s.d.).

The samples were always analysed in a random order to cancel out potential bias as analysis progressed (induced by e.g. heating of the instrument towards the end of an analysis session).

Table 1. THg concentration in certified reference samples and measured THg concentrations in the same reference samples.

<i>Reference sample</i>	<i>Reference sample, certified THg [ng/g] (± 95 % conf. interval)</i>	<i>Reference sample, measured THg [ng/g] (± 95 % conf. interval) DMA-80, Milestone</i>
NIST-1515, Apple Leaves	43.2 ± 2.3	42.4 ± 4.6 (n = 84)
ERM-CC141, Loam Soil	83 ± 17	78 ± 10 (n = 52)
ERM-CD281, Rye Grass	16.4 ± 2.2	15.9 ± 2.0 (n = 28)

3. Results

3.1. Mire characterisation

A general characterisation of the mire age classes is given in the site description (methods section). Though this description includes all 15 chronosequence mires, only 10 of these mires was sampled in this project. To further specify the characteristics of the 10 mires investigated herein, data from Wang et al. (2020) is used to specify the characteristics of the 10 mires. Cumulated peat mass and water content are however based on data from this project.

Cumulated peat mass (0-50 cm) correlates significantly with the actual mire age (i.e., the mire age expressed as number, not mire age class) ($P < 0.001$, $R^2 = 0.90$), as well as elevation ($P < 0.001$; $R^2 = 0.98$) and C ($P = 0.031$; $R^2 = 0.46$) (positive correlations). Water content (i.e., water lost in drying) is inversely correlated with mire age ($P < 0.001$, $R^2 = 0.91$). Though the peat cores were tightly sealed at the bottom and held upright after sampling, we do acknowledge that there is some uncertainty related to this measure (due to water seepage from the peat cores). Other significant inverse correlations with mire age are MeHg ($P = 0.019$, $R^2 = 0.52$), magnesium ($P = 0.039$, $R^2 = 0.43$), and potassium ($P = 0.050$, $R^2 = 0.40$). See Fig. S2 for further correlations between biogeochemical factors at the 10 mires from the chronosequence used in this project.

3.2. Freeze-dried vs. air-dried Hg and bulk density

A sub-set of samples were freeze-dried to evaluate the loss of Hg via air-drying of peat-samples at 60 °C in 96 h. Comparing sub-samples from the same peat cores, and the same depth, the THg content in the air-dried samples corresponds to 94.8 % (median value) of the THg content in the freeze-dried samples (Figs. S47-82). This difference between freeze-dried and air-dried THg content is significant using a two tailed Wilcoxon Signed-Rank Test for Paired Samples ($P = 0.017$). We therefore acknowledge a slight underestimation of the median Hg content in our results by ~5%.

The fact that the Hg concentrations are higher in some air-dried than freeze-dried samples is possibly explained by the sub-sampling variability and analytical uncertainty (for analytical uncertainty see table 1). The uncertainty induced by sub-sampling stems from first splitting each 2 cm disc (produced by slicing of the peat cores), of which one half was to be air-dried and the other half to be freeze-dried. Following the initial sub-sampling, the respective half discs were sub-sampled of ~10% (~1 g) for milling and homogenisation of the half discs. 0.025-0.1 g of this homogenous powder were finally analysed for Hg. Though we do not have an exact number to declare the uncertainty by the sub-sampling, it is likely that the sub-sampling adds some uncertainty to the final result.

There is no difference in dry bulk density between air-dried (60 °C) and freeze-dried samples (Two Tailed Wilcoxon Signed-Rank Test for Paired Samples). The medians between the dry bulk densities of the two drying methods differs with 0.7%, where air-dried samples are slightly more dense than freeze-

dried samples. The difference between cumulative THg derived from air-dried and freeze-dried samples is consequently smaller (and insignificant) than the difference in THg concentrations between the two drying methods (cumulative THg depends on both THg concentration and peat accumulation). The median cumulative THg content in air-dried samples corresponds to 97.3 % of the THg in freeze-dried samples. See Fig. S95-97 for relation between THg concentration, peat bulk density, and cumulative THg in air-dried and freeze-dried samples.

The volatile elemental Hg (Hg^0) is readily lost during heating (Biester & Scholz 1996). The proportion of Hg lost at 60 °C (96 h) could therefore indicate the chemical speciation of Hg in the samples. The proportion of Hg lost during heating (ratio of air-dried/freeze dried Hg concentration) correlates significantly with mire age (i.e., more Hg lost at old than at young mires) ($P = 0.035$; $R^2 = 0.93$) (Fig. S98). This however only yields for the 10 cm underlaying the GWT. It should furthermore be declared that data of Hg lost during heating and biogeochemical parameters only were available for four of the mires.

3.3.Hg and bulk density profiles

For the statistics of the 50 cm profiles, three of the ten mires are considered outliers and are thus excluded. Two of those (S02 and S70) are excluded from the 50 cm profiles since the mires are shallow (< 50 cm peat depth). Though it would have been possible to normalise or extrapolate the Hg content in the shallow mires, this would have biased the data towards shallow peat. It is worth repeating that our purpose is to study Hg retention in relation to mire age, and that the assumption of constant age at 0-50 cm is a key factor. These mires are however not considered outliers when the THg 0-10 cm under the GWT is reported, since the peat depth of the shallow mires are both >10 cm below the GWT.

The two excluded mires mentioned above are both young mires. In addition to this, an intermediate mire (S14) is excluded from the 50 cm profiles. The excluded intermediate mire deviates in terms of peat characteristics with substantial contribution from aquatic macrophytes. This mire is despite this included in Figs. 10-11 to enable a comparison with Wang et al (2020).

3.3.1. Lawn Hg concentration depth profiles

There is a peak apparent in Hg concentration at ~25 cm depth that is consistent for young (2 mires), intermediate (2 mires), and old mires (4 mires) when looking at the lawn microtopography (Fig. 4; Table 2). The two intermediate mires are reported in two separate profiles classes (mentioned as *intermediate 1* and *2* in Fig. 4), due to the large deviation among these two mires. The median peak Hg concentrations are 75 (young), 97 (intermediate 1), 138 (intermediate 2), and 105 ng g^{-1} (old).

Two peat cores were sampled from each mire class (e.g., young, intermediate, old lawn). The median throughout each sample profile is compared and reported in Fig. 5 (41, 41, and 33 ng g^{-1} for young, intermediate, and old mires respectively). Considering the intermediate mires as two separate classes,

the order of median THg concentrations results in intermediate 1 (25) < old < young < intermediate 2 (70 ng g⁻¹).

Since the mire surface was defined as depth zero, the top Hg concentrations in Fig. 4 represents the Hg concentration in the mire vegetation. It is apparent that the Hg concentration profiles is consistent regardless of mire age (Figs. S2-7). The median Hg concentrations at the bottom of the young and old profiles are also consistent. There is however, a large deviation among the intermediate lawn class.

Fig. 4. Lawn THg concentration (nanogram total Hg per gram dry peat mass) (a) and dry bulk density (b) for young, intermediate (mire 1 & 2), and old mires. Young and old mires are displayed as averages of two (n (total number of peat cores) = 4) and four mires (n = 8) respectively. The two intermediate mires (n = 4) are reported separately due to the strong deviation between the profiles. For deviation within the young and old lawn class see Fig. S4, S8.

None of the age classes differs significantly from each other; neither in terms of median nor peak Hg concentration (Fig. 5) (The Mann-Whitney Test for Two Independent Samples and 95 % confidence level used for testing Hg concentration and peat bulk density). A narrower confidence interval would however lead to significant differences between young-intermediate (P = 0.057) and young-old (P = 0.073) THg peak concentration (Fig. 5b).

Fig. 5. Median (a), and maximum (b) total Hg concentration of 16 peat cores from 8 different mires. 2 young mires (n (peat cores) = 4), 2 intermediate mires (n = 4), and 4 old mires (n = 8). Median THg concentration is indicated by the black line in each box.

3.3.2. Lawn peat bulk density

The peat bulk density in the superficial 50 cm of the mire profile increases with mire age. Median peat bulk density for young, intermediate, and old age classes are 0.045, 0.057 (int. 1 = 0.066, int. 2 = 0.046), and 0.064 g cm⁻³ respectively. There is a significant difference between young and old mire median bulk density ($P = 0.0081$) (Fig. S26).

3.3.3. Lawn peat profiles cumulative Hg and peat mass

The median cumulative THg is 1.14, 1.61, and 1.34 mg m⁻² for young, intermediate, and old mires respectively (Fig. S53). Dividing the deviating intermediate age class into two categories yields an order of intermediate 1 (1.1) < young < old < intermediate 2 (2.4 mg m⁻²) (Fig. 6). The large deviation among the intermediate mires implies that this age class should be interpreted with caution.

Fig. 6. Lawn cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) for young (2 mires, $n = 4$), intermediate (2 mires, $n = 4$), and old mires (4 mires, $n = 8$). The intermediate age classes deviate strongly within the class and is reported as intermediate mire 1 and 2.

3.3.4. Hummock Hg concentration

Hummocks are absent among the young mires with peat depth > 50 cm. The young age category is therefore not represented in the following section where hummock-microtopography results are presented.

Median THg concentration for the hummock depth profiles is 39 and 52 ng g^{-1} for intermediate and old mires respectively. There is a large deviation in THg concentration within the intermediate age class also for hummocks. Interestingly, the median THg concentration at intermediate mire 1 (43) is larger than intermediate mire 2 (35 ng g^{-1}) for hummocks. This is the inverse relationship compared to the lawn microtopography. Median THg concentration is however smaller at both intermediate mires compared to the old age class (intermediate 2 $<$ intermediate 1 $<$ old). It should be restated that the *median THg concentration* denotes the median value of all median values from each peat core (totally 4 intermediate and 8 lawn peat cores). The twofold calculation of the median values comes from the calculation of the median value depth wise, and later between peat cores. This is not to be confused with the average THg and density profiles (Fig. 7).

Though the THg peak concentrations varies within the two age classes (Fig. 8b), it follows the same order as the median THg concentrations: Median THg peak is smaller at intermediate than for old mires.

Fig. 7. THg concentrations (a) and dry bulk density (b) for hummock microtopographical units divided into intermediate (2 mires, $n = 4$) and old (4 mires, $n = 8$) mires.

The 12 cores used for average profiles in Fig. 7 are plotted for median and peak THg concentration (Fig. 8). None of the differences between intermediate and old hummocks are significant.

Fig. 8. Median (a) and maximum (b) total Hg concentration of 2 intermediate ($n = 4$) and 4 old ($n = 8$) mires. Median THg concentration is indicated by the black line in each box.

3.3.5. Hummock peat bulk density

Median peat bulk density of the hummock profiles is 0.037 and 0.036 g cm⁻³ for intermediate and old age classes respectively. There is no significant difference between intermediate and old hummocks when comparing median bulk density (Fig. S28).

3.3.6. Hummock peat profile cumulative Hg and peat mass

The median cumulative THg for intermediate mires are 1.25 for intermediate and 1.61 mg m^{-2} for old mires (Fig. 9). It is however noteworthy that there is a strong deviation between the two intermediate mires. In similarity with the median THg concentration, the cumulative THg is larger for intermediate mire 1 than intermediate mire 2.

Fig. 9. Hummock cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) for intermediate (2 mires, $n = 4$), and old mires (4 mires, $n = 8$). The intermediate age classes deviate strongly within the class and is reported as intermediate mire 1 and 2.

3.3.7. Lawn and hummock comparison - Hg concentration

Since hummocks are absent from the young age class (if mire depth > 50 cm), young samples were excluded for lawn to enable a side-to-side comparison. Median THg concentration for hummocks (44 ng g^{-1}) is significantly larger than for lawns (34 ng g^{-1}) ($P = 0.0036$). Though the distribution of THg concentrations varies within and between the two classes, the THg concentration of the uppermost sample is similar from all mires (these uppermost samples are of the mire vegetation) (Fig. 10).

The median THg peak for hummocks (130 ng g^{-1}) is also significantly larger than for lawns (97 ng g^{-1}) ($P = 0.028$) (Fig. 11b). Although the variability between peak THg values is larger for hummocks than for lawns, it is apparent that the hummock peak is found deeper than the lawn THg concentration peak.

Fig. 10. Average total Hg concentration (a) and dry bulk density (b) for the mire microtopographies hummock and lawn. Both plots are represented by 2 intermediate ($n = 4$) and 4 old mires ($n = 8$).

Fig. 11. Median (a) and maximum (b) total Hg concentration of hummock and lawn peat cores (each 6 mires, $n = 12$). Median THg concentration is indicated by the black line in each box.

3.3.8. Peat bulk density lawn and hummock

The median bulk density is 0.063 g cm^{-3} for lawn and 0.036 g cm^{-3} for the hummock microtopography. There is a significant difference between the two microtopographical classes ($P < 0.001$). For the average bulk density plot, there is a relatively small deviation above the assumed GWT ($\sim 5 \text{ cm}$ for lawns, ~ 25 for hummocks), although the profiles deviate below the GWT (Figs. S22, S24).

3.3.9. Cumulative Hg and peat mass in lawn and hummock peat profiles

The cumulative dry peat mass in the top 50 cm peat is significantly higher for lawns than for hummocks ($P < 0.001$) (Figs. 12a, S40). The difference between hummock and lawn cumulative THg is however not significant (Figs. 12, S43). The latter is influenced by the fact that the lawn microtopography generally accumulates more peat (according to our samples), simultaneously as THg concentrations are higher for hummocks than for lawns.

Fig. 12. Cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) for hummock (6 mires, $n = 12$) and lawn (6 mires, $n = 12$) microtopographies.

3.3.10. Hg and peat bulk density profiles summary

The average Hg concentrations at 0-2 cm mire depth of young, intermediate, and old mires are not significantly different. Though the total amount of Hg accumulated in the 0-50 cm peat layer increases with mire age, there is also an increase in peat accumulation (according to peat mass) as the mires age (only considering the superficial 50 cm) (Table 2).

Table 2. Summary of Hg and density data for 0-50 cm peat depth.

<i>Observation</i>	<i>Young Lawn</i>	<i>Intermediate Lawn</i>	<i>Old Lawn</i>	<i>Intermediate Hummock</i>	<i>Old Hummock</i>
<i>Median cumulative</i>					
<i>THg [mg m⁻²]</i>	1.4	1.6	1.3	1.3	1.6
<i>^aMedian THg</i>					
<i>concentration [ng g⁻¹]</i>	41	41	34	39	52
<i>Median surface</i>					
<i>concentration [ng g⁻¹]</i>	19	19	20	25	22
<i>Median peak</i>					
<i>concentration [ng g⁻¹]</i>	75	114	105	129	154
<i>Median bottom</i>					
<i>concentration [ng g⁻¹]</i>	32	33	21	68	74
<i>Median peak</i>					
<i>depth [cm]</i>	26	31	25	42	43
<i>Median peat bulk density</i>					
<i>peak [g cm⁻³]</i>	0.067	0.13	0.10	0.076	0.083
<i>Median peat bulk density</i>					
<i>bottom [g cm⁻³]</i>	0.041	0.12	0.093	0.064	0.065
<i>Median total peat</i>					
<i>mass [kg m⁻²]</i>	23	30	33	21	22

^aMedian of all median Hg concentrations for each sample (peat cores).

3.4.Relation between THg and %MeHg

A previous study at the chronosequence reported a negative correlation between THg and MeHg% (Wang et al. 2020). In contrast to the results reported above, the previous study was only conducted on 10 cm peat cores, 0-10 cm below the growing season average GWT. MeHg was not measured in this study, but to test this relationship with our samples, THg was plotted against %MeHg from Wang et al. (2020). While the correlation between THg and %MeHg is significant when using THg-data from Wang et al. (2020) ($P = 0.0062$, $R^2 = 0.63$), the negative relationship is not as strong, when using data of THg from our study and %MeHg from Wang et al. (0-10 cm under the long term GWT) ($P = 0.015$, $R^2 = 0.24$) (Fig. 13). The same test was also made for the THg of the full 50 cm cores. The negative tendency

with %MeHg is still present, but weaker than at 0-10 cm ($P = 0.21$, $R^2 = 0.19$) (Fig 13). The mires considered outliers in previous sections are included in Fig. 13.

Fig. 13. %MeHg of total Hg from Wang et al. (2020) (X-axis) vs. THg per square meter lateral mire surface per cm vertical peat depth (Y-axis). Red colour = young mires, blue = intermediate, grey = old. a, b indicates that the average full core is not 50 cm (32, 16 cm respectively). See table S1 for numeric values.

4. Discussion

It has been hypothesized that more Hg in less MeHg rich peat is an indication that the same processes that methylate Hg also make it more susceptible to mobilization (lateral runoff or vertical re-emission, most likely the latter) (Åkerblom et al. 2013; Osterwalder et al. 2017; Wang et al. 2020). A confounding factor in Wang et al.'s chronosequence evidence is that the MeHg rich mires, are also younger mires, even though it was assumed that the age of the superficial peat sampled just below the water table was the same. This study examines this hypothesis with three research questions (RQ).

4.1.RQ1: Do the chronosequence mires get Hg from the atmosphere into the surface peat at the same rate? (surface peat gravimetric Hg concentrations)

The THg concentrations at the mire surface and topmost peat, is similar disregarding of age classes and mire vegetation. This is illustrated by the low deviation at the mire surface within and between age classes (Fig. 14; Table 2). The THg concentration at the surface (0 - 2 cm) is only slightly higher for hummocks than for lawns despite the distinct differences in vegetation types, primary production, and hydrology commonly found between the two microtopographies (Rydin et al. 1999; Moore et al. 2019).

Fig. 14. Lawn (a) and hummock (b) average THg concentration. Error bars indicate one standard deviation of how all lawn samples and how all hummock samples deviate. The dashed line the approximate ground water table. The approximate water table was not measured in the field. This is an estimation of the typical distance to the ground water table in lawns and hummocks.

In contrast to our results, another study (Rydberg et al. 2010) from the Umeå-region found differences in Hg concentration between vegetation species: Differences were confirmed both between different *Sphagnum* species, and between mosses and vascular vegetation. Other studies have reported a

difference in Hg concentration between hummock and lawn vegetation (i.e., shrubs vs. *Sphagnum*-species) (Zhang et al. 2009), though we only found a slight difference (Hg concentration at 0-2 cm mire depth). Differences between hummock and lawn vegetation were explained by differences in leaf area indices, as dry deposition of elemental Hg ought to be the dominant deposition mechanism to mires (Jiskra et al. 2015; Enrico et al. 2016; Obrist et al. 2017). The minor contribution of shrubs to the vegetation (i.e., larger leaf area index than mosses) at the hummocks present on the chronosequence is possibly insufficient to result in a significant difference in Hg concentration between hummock and lawns.

The similar Hg concentrations between vegetation species suggests that the Hg concentration in mire vegetation is proportional to the Hg concentration in the atmosphere (assuming that atmospheric input is the dominant source of Hg in vegetation; Jiskra et al. 2015; Enrico et al. 2016). The presence of an active mechanism of Hg exchange between the vegetation (and topmost peat) and the atmosphere is hence possible. Negative net Hg deposition (i.e., Hg evasion) has been recorded at Degerö Stormyr (Osterwalder et al. 2017), which is one of the mires sampled in this project (Degerö lawn = DLB, Fig. S7; hummock = DHB, Fig. S12). This study (along with others) would be consistent with net Hg deposition to mires being a bi-directional process. The surface Hg concentration would thus represent a balance in this process related to the properties of the air-peat surface interface, and the concentrations on each side of that interface (Zhang et al. 2009).

4.2.RQ2: Is the distribution of the Hg in the top 50 cm similar along the chronosequence (peak depth and magnitude, as well as bottom concentrations)?

Our observations of cumulative THg in the topmost 50 cm peat indicate an increase in THg with mire age, this is however not the case for the median THg concentrations (Figs. 4-5, Table 2). The median THg concentrations rather suggests that Hg is equally, or even more efficiently, retained in young mires than old ones (lawn microtopography).

There is a peak in THg concentration at ~25 cm consistent for all three age classes at the lawn microtopography. The general pattern of a distinct Hg peak, likely reflecting the maximum Hg concentration in the atmosphere, is commonly found in peatlands (Biester et al. 2002; Bindler et al. 2004; Roos-Barraclough & Shotyk 2003; Shotyk et al. 2003; Franzen et al. 2004; Coggins et al. 2006; Farmer et al. 2009; Rydberg et al. 2010; Allan et al. 2013). Hg enrichment since the industrial revolution is also documented in other archives, such as ice cores, and lake and marine sediments (Landers et al. 1995; Corella et al. 2017).

There is a distinct peak in Hg concentration also in hummocks. The Hg peaks in hummock profiles are however larger than the peak in the lawn profiles; 130 compared to 97 ng g⁻¹. High Hg retention in hummocks has also been observed by others (Norton et al. 1997; Benoit et al. 1998; Outridge et al.

2011). The hummock peak is furthermore found deeper relative to the mire surface (~35 cm), indicating the importance of the GWT depth for the Hg concentration (Fig. 15).

The magnitude of the THg peaks does not differ significantly between the age classes, neither for hummock nor for lawns. That the THg maximum is larger in old than younger peatlands in lawns, are however coherent with the hypothesis that less Hg is retained in young peatlands. This pattern is also consistent for hummocks (intermediate < old peaks), though there is a large variation within both intermediate and old mires.

At a certain depth in the peat profile there is a THg concentration corresponding to the atmospheric Hg level before anthropogenic influence (Biester et al. 2002; Givelet et al. 2003). Consulting age models from other mires, we assume our peat cores to reach beyond the industrial revolution, which presumably causes the peak in THg at ~25 cm in lawns and ~35 in hummocks (Biester et al. 2002; Roos-Barracough & Shotyk 2003; Shotyk et al. 2003; Allan et al. 2013). The THg concentration at the bottom of the peat profiles are consistent throughout young and old mires (lawn). The bottom concentration exceeds the THg concentration at the surface in young mires, while bottom and surface concentrations are equal in old mires. Considering the consistent surface Hg concentrations between the mires, we cannot exclude the possibility that the variable bottom Hg concentrations are due to post depositional processes or differences in peat age at 50 cm mire depth. The peat cores need to be dated to increase the accuracy of the mire profiles as indicators of pre-anthropogenic Hg levels.

4.3.RQ3: Are the chronosequence mires similar in their retention of Hg? (cumulative Hg)

As previously mentioned, Wang et al. (2020) found an inverse relationship between THg and MeHg in the lawn microtopography 0-10 cm under the long-term GWT. This coincidence led to the hypothesis that the same process that methylate Hg also favours Hg mobility, possibly through Hg evasion.

Though the data from Wang et al. produced a stronger inverse correlation with MeHg, THg from peat sampled in this study is still inversely correlated with MeHg (data from Wang et al. 2020) (Fig. 13). In the following section, we discuss how cumulative Hg varies along the chronosequence.

The cumulative THg follows the pattern of young < old (< intermediate) for the lawn microtopography (Fig. 5) (intermediate in parenthesis due to the large uncertainty). The difference between cumulative THg between young and old mires at the lawn microtopography is statistically significant ($P = 0.028$). The hummock samples moreover indicate an increase in THg with mire age. Assuming that all the mires have received the same input at the surface (see RQ1), this supports the hypothesis that Hg mobility is greater in the younger mires with higher MeHg content, if the peat sampled at 0-50 cm is of the same age throughout mire age classes. This furthermore assumes that the %MeHg gradient across the chronosequence is valid also for the water-logged depth in hummocks.

When considering the cumulative THg, it is assumed that the age of the superficial 50 cm peat is consistent throughout age classes. Of course, peat accumulates at the mire surface, and a key difference

between the mire age classes is the distance to the mire bottom (underlying nutrient-rich sediment). There *could* however be a difference in the net peat accumulation between the three age classes, due to differences in peat formation and decomposition rates. Important factors governing this balance are the mire vegetation type, nutrient stoichiometry, hydrology, oxygen accessibility, pH, and temperature (Moore 1989; Moore & Basiliko 2006; Wang et al. 2015; Drzymulska 2015). The three age classes do differ in these parameters, which adds to the uncertainty of the superficial peat age.

Another factor problematising the assumption that the superficial 50 cm represents the same age is the peat density. Although the density could be a problematic measure for peat decomposition (Biester et al. 2003; Roos-Barraclough & Shotyk 2003), it is evident that peat mass increases with mire age (Figs. 5, 7). To conclude if this means that the superficial peat is older at old mires than at young mires, the peat needs to be dated. No dating will however be done in this project and the superficial peat is therefore assumed to be of the same age. We do, however, acknowledge the uncertainty brought by the undated samples. Without dating, it will be difficult to dismiss the alternative suggestion that it is peat accumulation that determines Hg content.

4.4. Estimation of potential Hg evasion

Assuming that the difference in Hg content between young and old mires ($\Delta 0.35 \text{ mg/m}^2$) is entirely due to Hg evasion since 1980 from the top 50 cm, $9.1 \text{ } \mu\text{g/m}^2$ more Hg was evaded annually from young mires than old mires (lawn). The corresponding number for the hummock microtopography is $8.4 \text{ } \mu\text{g/m}^2/\text{y}$ (Δ intermediate – old mires). A study conducted on one of the old mires (denoted DLB and DHB in the SI) 2013-14 concluded an annual net Hg evasion of $10 \text{ } \mu\text{g/m}^2/\text{y}$ (Osterwalder et al. 2017). The annual net Hg evasion from young mires at the lawn microtopography would therefore be $19.1 \text{ } \mu\text{g/m}^2$, or $18.6 \text{ } \mu\text{g/m}^2$ in intermediate hummocks.

Understanding of Hg retention in peat is important for the use of peat as an archive for Hg deposition. Though different peatland types are sometimes considered when peatlands are used as an archive for Hg deposition (Biester et al. 2002; Talbot et al. 2017), peatland age is rarely considered (no studies to our knowledge for peat profiles $\geq 50 \text{ cm}$). Our results indicate that peatland age (and peatland nutrient status) could be an important parameter to consider when modelling net Hg retention in peatlands. We therefore encourage future studies to further explore the relation between Hg retention and peatland age for a more accurate reconstruction of past atmospheric Hg levels.

5. Conclusion

Another study (Wang et al. 2020) at the site reported an inverse relationship between total Hg and %MeHg, suggesting that the same processes that methylate Hg also make it more susceptible to mobilization. This hypothesis was tested by observing high resolution depth profiles of total Hg content at mire depth 0-50 cm for mires with varying methylation potential (which also corresponds to a gradient; from young high methylating mires to old less methylating mires).

We confirm that there in fact is a difference in cumulative Hg content along the mire chronosequence: Young mires generally contains less Hg than old mires. This difference is however driven by more accumulated peat down to 50 at old mires than at young mires, though Hg concentrations are generally consistent across the mire age gradient. To answer the question if high methylating mires retains less Hg, it will be crucial to know if the age of the superficial 50 cm peat is consistent throughout the chronosequence. The peat cores were namely not dated in this project.

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Appendix 1: Supplementary information

Fig. S1. Stainless-steel corer used for sampling of peat cores.

Fig. S2. Correlations of biogeochemical parameters of the 10 mires from the chronosequence used in this project. Circled correlation coefficients indicate a significant correlation (0.95 confidence interval). This data corresponds to the 10 cm of peat underlying the groundwater table. Age = Mire age. a) = Elevation (meter above sea level). GWL = Groundwater level.

Fig. S3. Young lawn gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores. The samples *S02H/LB* and *S70LB* are considered outliers for the average young lawn profile, since those samples are both < 50 cm.

Fig. S4. Young lawn average gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S5. Intermediate lawn gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores. The sample *S14H/LB* is considered an outlier for the average intermediate lawn profile. This mire differs from the other two mires in terms of mire vegetation and peat characteristics.

Fig. S6. Intermediate lawn average gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S7. Old lawn gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores.

Fig. S8. Old lawn average gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S9. Young hummock gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). This mire is considered an outlier for the average Hg concentration in hummocks since peat depth < 50 cm.

Fig. S10. Intermediate hummock gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores.

Fig. S11. Intermediate hummock average gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S12. Old hummock gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores.

Fig. S13. Old hummock average gravimetric total Hg concentration (nanogram per gram dry peat mass) (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S14. Young lawn dry bulk density (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores. Each profile is an average of two peat cores. The samples *S02H/LB* and *S70LB* are considered outliers for the average young lawn profile, since those samples are both < 50 cm.

Fig. S15. Young lawn average dry bulk density (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S16. Intermediate lawn dry bulk density (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores. The sample *S14H/LB* is considered an outlier for the average intermediate lawn profile. This mire differs from the other two mires in terms of mire vegetation and peat characteristics.

Fig. S17. Intermediate lawn average dry bulk density (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S18. Old lawn dry bulk density (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores.

Fig. S19. Old lawn average dry bulk density (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S20. Young hummock dry bulk density (X-axis) vs. depth (Y-axis). This mire is considered an outlier for the average density in hummocks since peat depth < 50 cm.

Fig. S21. Intermediate hummock dry bulk density (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores.

Fig. S22. Intermediate hummock average dry bulk density (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S23. Old hummock dry bulk density (X-axis) vs. depth (Y-axis). Each profile is an average of two peat cores.

Fig. S24. Old hummock average dry bulk density (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S25. Average lawn (young, intermediate, and old mires = 16 peat cores) dry bulk density (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation. The dashed line represents the assumed groundwater table (not measured in the field).

Fig. S26. Median peat density for young ($n = 4$), intermediate ($n = 4$), and old mires ($n = 8$) at the lawn microtopography.

Fig. S27. Average hummock (intermediate and old mires = 12 peat cores) dry bulk density (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation. The dashed line represents the assumed groundwater table (not measured in the field).

Fig. S28. Average (a) and median (b) peat density for intermediate ($n = 4$) and old mires ($n = 8$) at the hummock microtopography.

Fig. S29. Young lawn volumetric total Hg concentration (X-axis) vs. depth (Y-axis). Each mire is an average of two peat cores. The samples *S02H/LB* and *S70LB* are considered outliers for the average young lawn profile, since those samples are both < 50 cm.

Fig. S30. Young lawn volumetric total Hg concentration (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S31. Intermediate lawn volumetric total Hg concentration (X-axis) vs. depth (Y-axis). Each mire is an average of two peat cores. The sample *S14H/LB* is considered an outlier for the average intermediate lawn core. This mire differs from the other two mires in terms of mire vegetation and peat characteristics.

Fig. S32. Intermediate lawn volumetric total Hg concentration (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S33. Old lawn volumetric total Hg concentration (X-axis) vs. depth (Y-axis). Each mire is an average of two peat cores.

Fig. S34. Old lawn volumetric total Hg concentration (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S35. Young hummock volumetric total Hg concentration (X-axis) vs. depth (Y-axis). This mire is considered an outlier for the average Hg concentration in hummocks since peat depth < 50 cm.

Fig. S36. Intermediate hummock volumetric total Hg concentration (X-axis) vs. depth (Y-axis). Each mire is an average of two peat cores.

Fig. S37. Intermediate hummock volumetric total Hg concentration (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S38. Old hummock volumetric total Hg concentration (X-axis) vs. depth (Y-axis). Each mire is an average of two peat cores.

Fig. S39. Old hummock volumetric total Hg concentration (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation.

Fig. S40. Average lawn (young, intermediate, and old mires = 16 peat cores) volumetric total Hg concentration (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation. The dashed lined represents the assumed groundwater table (not measured in the field).

Fig. S41. Average hummock (intermediate and old mires = 12 peat cores) volumetric total Hg concentration (X-axis) vs. depth (Y-axis). The error bars indicate $\pm$ one standard deviation. The dashed lined represents the assumed groundwater table (not measured in the field).

Fig. S42. Young lawn cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (4 mires, $n = 8$). The samples *S02H/LB* and *S70LB* are considered outliers for the average young lawn profile, since those samples are both < 50 cm.

Fig. S43. Average young lawn cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (2 mires, $n = 4$). The error bars indicate $\pm$ one standard deviation.

Fig. S44. Intermediate lawn cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (3 mires, $n = 6$). The sample *S14H/LB* is considered an outlier for the average intermediate lawn profile. This mire differs from the other two mires in terms of mire vegetation and peat characteristics.

Fig. S45. Average intermediate lawn cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (2 mires, $n = 4$). The error bars indicate $\pm$ one standard deviation.

Fig. S46. Old lawn cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (4 mires, $n = 8$).

Fig. S47. Average old lawn cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (4 mires, $n = 8$). The error bars indicate $\pm$ one standard deviation.

Fig. S48. Young hummock cumulative total Hg vs. cumulative dry peat mass (a) and depth (b). This mire is considered an outlier for the average hummock profile since peat depth < 50 cm.

Fig. S49. Intermediate hummock cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (2 mires, $n = 4$).

Fig. S50. Average intermediate hummock cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (2 mires, $n = 4$). The error bars indicate $\pm$ one standard deviation.

Fig. S51. Old hummock cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (4 mires, $n = 8$).

Fig. S52. Average old hummock cumulative total Hg vs. cumulative dry peat mass (a) and depth (b) (4 mires, $n = 8$). The error bars indicate $\pm$ one standard deviation.

Fig. S53. Cumulative peat mass for young (4 peat cores), intermediate (n = 4), and old (n = 8) age classes at 0 – 50 cm mire depth.

Fig. S54. Cumulative peat mass for intermediate (4 peat cores) and old (n = 8) age classes at 0 – 50 cm mire depth.

Fig. S55. Cumulative peat mass for lawn (12 peat cores) and hummock ($n = 12$) microtopographies at 0 – 50 cm mire depth. Only intermediate and old age classes are represented to avoid bias related to mire age in the intermicrotopographical comparison.

Fig. S56. Cumulative total Hg (milligram THg per square meter) for young, (4 peat cores) intermediate ($n = 4$) and old ($n = 8$) age classes at 0 – 50 cm mire depth.

Fig. S57. Cumulative total Hg (milligram THg per square meter) for intermediate (4 peat cores) and old (n = 8) age classes at 0 – 50 cm mire depth.

Fig. S58. Cumulative total Hg (milligram THg per square meter) for lawn (12 peat cores) and hummock (n = 12) microtopographies at 0 – 50 cm mire depth. Only intermediate and old age classes are represented to avoid bias related to mire age in the intermicrotopographical comparison.

<i>Mire</i>	<i>Age class</i>	<i>Mire age</i>	<i>GWT [cm]</i>	<i>%MeHg^a</i>	<i>0-10 cm^bTHg Wang et al.</i>	<i>0-10 cm^bTHg this study</i>	<i>0-50 cm^bTHg this study</i>
<i>S02</i>	Young	69	11	24	57	20	15
<i>S10</i>	Young	539	6	16	26	10	23
<i>S13</i>	Young	363	9	10	51	24	23
<i>S70</i>	Young	180	10	9	86	25	32
<i>S14</i>	Intermediate	1341	12	16	27	11	11
<i>S18</i>	Intermediate	1370	11	2	138	16	22
<i>S52</i>	Intermediate	1278	2	11	52	7	48
<i>S26</i>	Old	2397	13	2	107	32	27
<i>S29</i>	Old	2292	13	3	165	26	27
<i>S65</i>	Old	3259	11	3	151	60	55

Table S1. Summary of mire age, groundwater table depth, % methylmercury (of total Hg) and total Hg from Wang et al. (2020) and this study.

- % methylmercury of total Hg from Wang et al. (2020).
- Total Hg with the unit $\mu\text{g}/\text{m}^2/\text{cm}$ (THg per square meter mire surface per centimetre mire depth).

<i>Mire</i>	<i>Age class</i>	<i>Lawn characteristic plant species</i>
<i>S02</i>	Young	<i>Sphagnum squarrosum</i>
<i>S10</i>	Young	<i>Sphagnum fallax</i> , <i>Warnstorfia procera</i>
<i>S13</i>	Young	<i>S. fallax</i> , <i>Sphagnum riparium</i>
<i>S70</i>	Young	<i>Sphagnum lindbergii</i> , <i>S. riparium</i>
<i>S14</i>	Intermediate	<i>S. majus</i>
<i>S18</i>	Intermediate	<i>S. lindbergii</i>
<i>S52</i>	Intermediate	<i>S. majus</i>
<i>S26</i>	Old	<i>Sphagnum balticum</i> , <i>S. majus</i> , <i>S. papillosum</i>
<i>S29</i>	Old	<i>S. majus</i> , <i>S. balticum</i>
<i>S65</i>	Old	<i>S. balticum</i> , <i>S. papillosum</i>

Table S2. Characteristic plant species at the lawn microtopography for 10 of the mires. Table modified from Wang et al. (2020).

Fig. S59. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Young mire, lawn microtopography.

Fig. S60. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Young mire, lawn microtopography.

Fig. S61. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Young mire, lawn microtopography. Since only every second sample is available depth wise in this core, the cumulative values should be interpreted with caution. The plot is included to display any systematic differences between the subsamples.

Fig. S62. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Young mire, lawn microtopography.

Fig. S63. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Young mire, lawn microtopography.

Fig. S64. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Young mire, lawn microtopography.

Fig. S65. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 24-26 cm depth (n = 13). Young mire, hummock microtopography. The mire is shallow and sampling only possible to 26 cm of depth at this particular point at the mire.

Fig. S66. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 24-26 cm depth (n = 13). Young mire, hummock microtopography.

Fig. S67. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 24-26 cm depth (n = 13). Young mire, hummock microtopography.

Fig. S68. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, lawn microtopography.

Fig. S69. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, lawn microtopography.

Fig. S70. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, lawn microtopography.

Fig. S71. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, hummock microtopography.

Fig. S72. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, hummock microtopography.

Fig. S73. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, hummock microtopography.

Fig. S74. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, lawn microtopography.

Fig. S75. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, lawn microtopography.

Fig. S76. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, lawn microtopography.

Fig. S77. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Intermediate mire, hummock microtopography.

Fig. S78. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Intermediate mire, hummock microtopography.

Fig. S79. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Intermediate mire, hummock microtopography. Since only every second sample is available depth wise in this core, the cumulative values should be interpreted with caution. The plot is included to display any systematic differences between the subsamples.

Fig. S80. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Old mire, hummock microtopography.

Fig. S81. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Intermediate mire, hummock microtopography.

Fig. S82. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 2-4 cm ... 48-50 cm depth (n = 25). Old mire, hummock microtopography.

Fig. S83. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, lawn microtopography.

Fig. S84. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, lawn microtopography.

Fig. S85. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, lawn microtopography. Since only every second sample is available depth wise in this core, the cumulative values should be interpreted with caution. The plot is included to display any systematic differences between the subsamples.

Fig. S86. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, hummock microtopography.

Fig. S87. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, hummock microtopography.

Fig. S88. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, hummock microtopography. Since only every second sample is available depth wise in this core, the cumulative values should be interpreted with caution. The plot is included to display any systematic differences between the subsamples.

Fig. S89. Total Hg concentration of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, hummock microtopography.

Fig. S90. Dry bulk density of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, hummock microtopography.

Fig. S91. Cumulative THg content (milligram per square meter) (X-axis) vs. cumulative dry peat mass (Y-axis) of freeze dried and air dried (60 °C) subsamples at 0-2 cm, 4-6 cm ... 48-50 cm depth (n = 13). Old mire, hummock microtopography. Since only every second sample is available depth wise in this core, the cumulative values should be interpreted with caution. The plot is included to display any systematic differences between the subsamples.

Fig. S92. Ratio of Air dried and Freeze dried [Hg]. A ratio <1 indicates loss of Hg in air drying (n=203). Samples with air dried > freeze dried [Hg] could possibly be explained by subsampling or analytical uncertainty. One data point (>200%) is not visible in the figure.

Fig. S93. Histogram of air dried vs. freeze dried ratios. Median = 94.8 %.

Fig. S94. Average air dried vs. freeze dried [Hg] at each depth.

Fig. S95. Freeze-dried (X-axis) vs. Air-dried (Y-axis) THg [ng/g] (n=199). 5 outliers were excluded ($Q1, Q3 \pm \text{interquartile range} * 1.5$). 4 of these 5 outliers represents larger THg concentration in air-dried than freeze-dried samples. This figure should therefore only be interpreted as the relation between the THg concentrations, and not as a measure on THg retention, after air- or freeze-drying. Though the residuals are generally normally distributed, there is a slight bias for negative residuals at intermediate THg concentrations and positive residuals at high THg concentrations.

Fig. S96. Freeze-dried (X-axis) vs. Air-dried (Y-axis) dry bulk density [g/cm^3] ($n=189$, excluding outliers). 14 outliers were excluded ($Q1, Q3 \pm \text{interquartile range} * 1.5$). 11 of these 14 outliers represents larger bulk densities in air-dried than freeze-dried samples. This figure should therefore only be interpreted as the relation between the bulk densities after air- or freeze-drying. The residuals of the linear model are slightly right-skewed.

Fig. S97. Freeze-dried (X-axis) vs. Air-dried (Y-axis) cumulative THg [$\mu\text{g} / \text{m}^2$ (mire surface) / cm (mire depth)] ($n=185$, excluding outliers). 18 outliers were excluded ($Q1, Q3 \pm \text{interquartile range} * 1.5$). 17 of these 18 outliers represents larger cumulative THg in air-dried than freeze-dried samples. This figure should therefore only be interpreted as the relation between the cumulative THg, and not as a measure on THg retention, after air- or freeze-drying.

Fig. S98. Correlations (correlation coefficients displayed) between biogeochemical parameters and the ratio of air-dried/freeze-dried Hg concentration, dry bulk density, and cumulative Hg at the 10 cm underlying the groundwater level (n=4). Though we only have four data points, there is a significant correlation (0.95 confidence interval) between air-dried/freeze-dried Hg concentration and mire age (circled correlation coefficient and plotted with a linear function). Age = Mire age. GWL = Groundwater level. [Hg] = Ratio of air-dried/freeze-dried Hg concentration. ρ = Ratio of air-dried/freeze-dried dry bulk density. Cum Hg = Ratio of air-dried/freeze-dried cumulative Hg.