

Nationalmuseet Bevaring & Naturvidenskab



Preservation conditions at dipwells MB48 and MB49 under the Hanseatic Museum, Bryggen, Bergen

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Title:
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Bergen

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Summary:
In March 2014 two new dipwells, MB48 and MB49, were installed alongside the Hanseatic Museum, in the southernmost part of the original Bryggen area, in order to evaluate ongoing subsidence. Soil samples from the boreholes were analysed, and groundwater was sampled on the 16th June 2014 for a full groundwater analysis. Loggers measure the groundwater level and temperature in the dipwells every hour. The results are presented and discussed in this report, with special emphasis on the actual preservation conditions around the dipwells.

The results show that the upper soil layers are highly organic and periodically above the groundwater level. Although these layers are in a poor state of preservation, oxygen consumption measurements show that they are highly reactive and thereby highly vulnerable to drainage. The deposits beneath the groundwater level are also organic and susceptible to decay. The proximity to the harbour means that decay through sulphate reduction could be a risk, as has earlier been shown for other dipwells at the quayfront on Bryggen. High concentrations of sulphur and pyrite in the soil at MB48 and 49 indicate that this has already taken place to some extent. The present-day decay rate for the deposits under the groundwater level depends on the supply of sulphate, which will be further elucidated through groundwater sampling over the coming years. Measurements of temperature within the dipwells indicate that soil temperatures beneath the Hanseatic Museum may be significantly increased by heat from the building. This could increase decay rates, especially during the winter, and thereby be of importance to the preservation conditions. Temperature measurement during winter will help to elucidate the extent of this and should therefore receive particular attention in the upcoming period.

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Appendix 2: Results from analysis of groundwater samples from MB48 and MB49 (Eurofins)

Introduction

The conditions in the archaeological deposits underneath the World Heritage Site Bryggen in Bergen have been thoroughly monitored for the last decade, and more than 40 dipwells have been installed in the area since 2001. In March 2014 two new dipwells, MB48 and MB49, were installed alongside the Hanseatic Museum in the southernmost part of the original Bryggen area, in order to study the preservation conditions and evaluate the ongoing subsidence that is affecting the building (Dunlop, 2014). These new dipwells are supplemental to dipwells MB34 and MB35 outside the building (Matthiesen, 2011), which were installed in the same area in 2010 to provide information on underground conditions in advance of a proposed railway development project (Bybane Nord). The National Museum of Denmark has been contracted by NIKU to evaluate the conditions of and threats to the archaeological deposits around these dipwells, based on results from analyses of soil and water.

Site and methods

In March 2014 the drilling work was carried out by Multiconsult AS and attended by archaeologist Rory Dunlop from the Norwegian Institute for Cultural Heritage Research, NIKU (Figure 1 and Table 1). Due to limited accessibility the drillings had to be made using a mini-rig and therefore the depth of the dipwells was limited to approximately 4 m. Loggers were installed in the dipwells, measuring the groundwater level and temperature every hour. The data is downloaded manually by Multiconsult. Nine soil samples from MB48 and MB49 were analysed at Eurofins for pH, dry matter content (i.e. the weight of the dried sample relative to the weight of the wet sample), loss on ignition (i.e. the weight loss when the dried sample is burned), water-soluble chloride, water-soluble sulphate, total sulphur, total phosphorus and total nitrogen, and three of the samples were also analysed for pyrite (measured as iron extracted in boiling HNO₃ after removal of non-pyritic iron). The laboratory reports are given in Appendix 1.

Measurements of oxygen consumption were made at the National Museum to investigate the reactivity of the collected soil samples. Measurements were made at 5 °C, according to Matthiesen (2007).

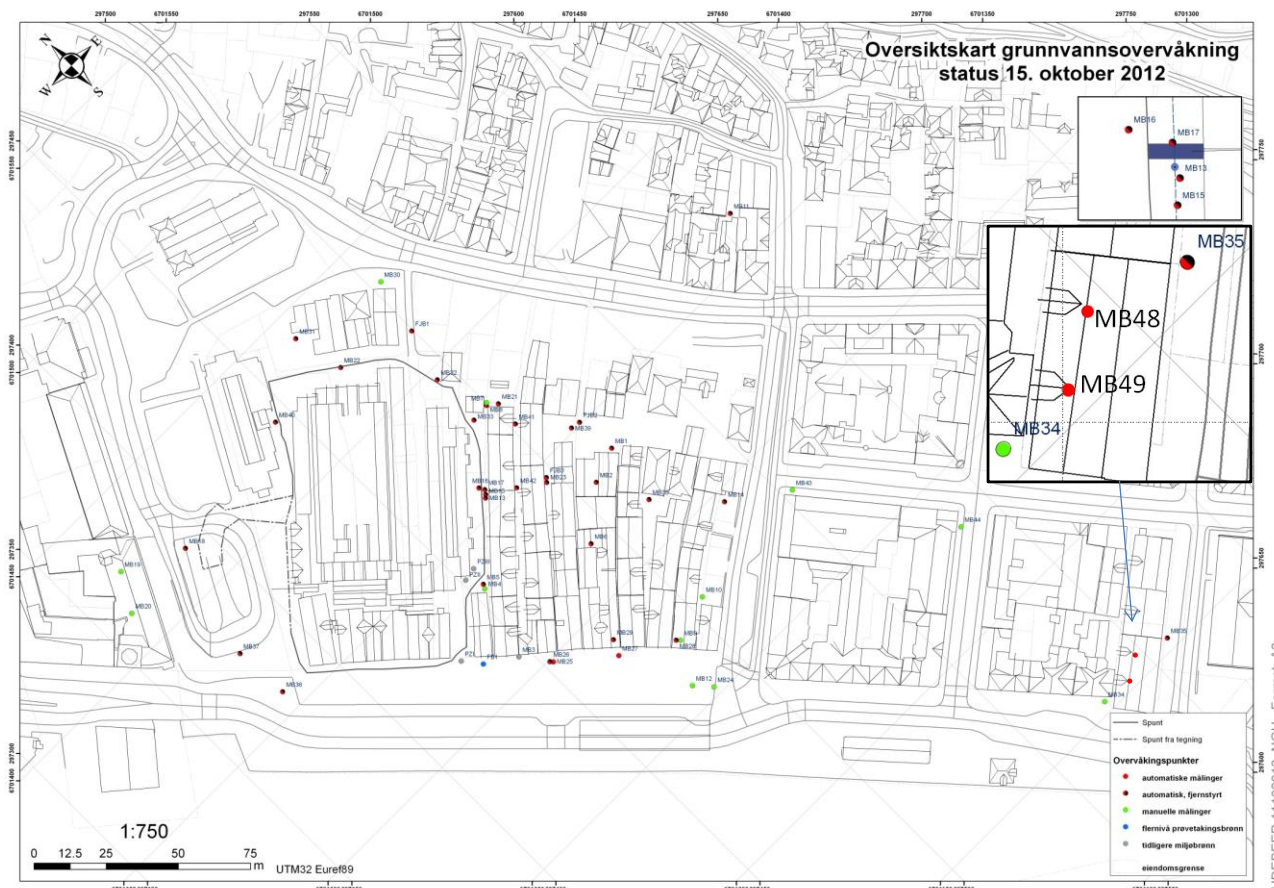


Figure 1: Map of Bryggen, showing the positions of MB48 and MB49 at the Hanseatic Museum in the southern part of Bryggen (red circles). Other dipwells are marked as well. Map after Hans de Beer, NGU.

Dipwell	East	North	Planking surface (m asl)	Soil surface (m asl)	Water intake, top (m asl)	Water intake, bottom (m asl)
MB48	297595.40	6701160.80	1.10	0.65	-1.85	-2.85
MB49	297588.85	6701155.65	1.05	0.60	-1.60	-2.60

Table 1: Position of dipwells (data from Dunlop, 2014)

On the 16th of June 2014 water was sampled from dipwells MB48 and MB49 (along with dipwells MB34 and MB35 outside the building) by Multiconsult. The dipwells were emptied before the actual sampling, to ensure that fresh water from the archaeological deposits was sampled. The water samples were filtered in the field (0.45 μm Gelman high capacity in-line filter). The samples were sent to the laboratory (Eurofins) and analysed for alkalinity, salt (sodium, chloride), nutrients (ammonium, nitrate, phosphate), redox active species (sulphate, nitrate, dissolved iron, dissolved manganese, sulphide, methane), and other major ions (calcium, magnesium, potassium). The reports from the laboratory are shown in Appendix 2.

Results and discussion

Description of the drilling cores

Figure 2 (left) shows the loss on ignition (LOI) and dry matter content of soil samples from drillings MB48 and MB49, along with a brief description of the different soil strata based on the archaeological description made by Dunlop (2014).

In MB48 the upper 0.35 m (down to 0.30 m asl) of the deposits are modern sandy humus and demolition deposits. From 0.30 m to 0.10 m the soil is highly organic (LOI = 40%), containing poorly preserved wood pieces (State of Preservation Scale SOPS = 2) with a strong odour of hydrocarbon indicating that the soil has been polluted by paraffin. The following 1 m (down to -0.90 m asl) consists of sand/gravel layers that contain bone, woodchips, hazelnut shells. This length of the drilling has a low LOI (18%) and is in a poor state of preservation (SOPS = 2). From -0.90 m asl and down to -1.90 m asl the soil is sandy with horizontal timber layers. Here the organic content is relatively high (40%) and the state of preservation is medium (SOPS = 3). The next layer, down to -2.85 m asl, is wet and relatively loose and contains many saw-chips, some woodchips and a few animal and fish bones. The LOI is very high (46-69%) but the state of preservation is considered poor (SOPS = 2). At -2.9 m asl the coring was abandoned in a layer of fine sand containing some seashell fragments, which may be natural deposits and seabed.

In MB49 the upper 0.8 m (down to -0.20 m asl) comprises modern layers with a mixture of timber and demolition layers, all of which are in a poor state of preservation (SOPS = 2) but with a very high organic content (LOI = 71%). The following 2.1 m (down to -2.30 m asl) consist of thick, wet, loose, sandy layers with some woodchips and many bone fragments. The organic content is low (LOI = 15-21) and the state of preservation is poor (SOPS = 2). The final layer (down to -2.60 m asl) is wet, loose and highly organic with many woodchips and a few bones. The organic content is very high (LOI = 63%) and the state of preservation is poor (SOPS 2).

Analysis of soil and ground water samples

The results from analysis of soil samples from MB48 and MB49 are presented graphically in Figure 2. Results from groundwater analysis of samples taken in MB48 and MB49 on 16th June 2014 are presented in Figure 3. For comparison, results from water samples taken from MB34 and MB35 on the same date are also shown.

The quality of the groundwater analyses has been checked in terms of ion balance, where the sum of positive charges should equal the sum of negative charges. This gives a good result for MB34 and MB48 (a deviation of only 1%), a reasonable result for MB49 (4% deviation) but a poor result for MB35 (28% more negative ions compared to positive ions). There may be several explanations for such a difference, such as for instance oxidation or precipitation processes during transport and storage of samples. The laboratory has measured the conductivity and the residue after drying of the samples (data in Appendix 2), both of which are in reasonable correspondence with measured ion concentrations. It is thus concluded that the laboratory measurements are fairly accurate, but some of the results from MB35 may be biased. The methane results may be too low compared to in situ conditions, as it is very difficult to avoid degassing during the sampling.

The groundwater analyses indicate a moderately reduced environment in MB48 and MB49: the ammonium content is high, but the concentrations of other reduced species (Fe^{2+} , Mn^{2+} , HS^- , CH_4) are only moderate (Figure 3). The only oxidant measured at a significant concentration in the water is sulphate, which is discussed later. Compared to dipwells MB34 and MB35 the concentrations measured in MB48 and MB49 show higher bicarbonate and ammonium concentrations during this sampling round, but equally high concentrations have earlier been measured in MB35 (Matthiesen, 2011).

The pH measured for both groundwater (pH 6.6-6.7) and soil (pH 6.9-8.0) are in the neutral region, which is the case for almost all samples from Bryggen. The pH of 8.0 measured in the soil samples from MB48 is at the high end, but similar values have been encountered at other dipwells.

The soil is relatively nutrient rich (N, P species) with some correlation between the nutrients and the loss on ignition measured in the soil, indicating that the nutrients are connected to the organic material. The C/N ratio of the soil samples are in the range 14-35 with an average of 24, which is similar to earlier values from Bryggen (average 20 ± 6 , 1 standard deviation).

It can be difficult to validate the quality of the soil data, but the results are similar to what has earlier been measured in the archaeological deposits at Bryggen (these earlier results are published in a range of reports for each individual dipwell on Bryggen, and compiled in an unpublished database).

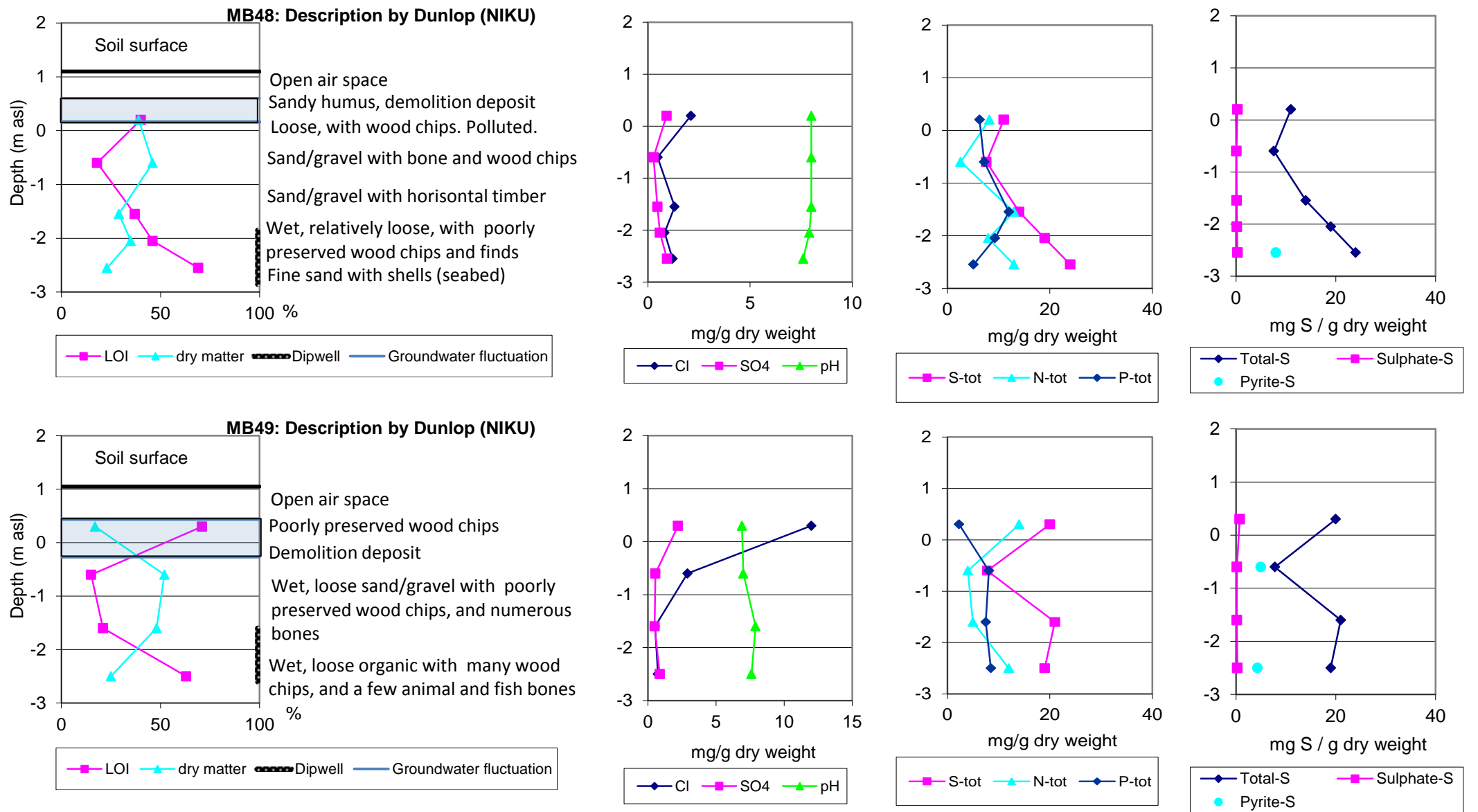


Figure 2: Description and soil analyses of drillings MB48 and MB49. LOI is the loss on ignition; filled symbols are data from Eurofins and open symbols data from Multiconsult. Cl and SO₄ is water extractable chloride and sulphate, S-tot, N-tot and P-tot is total amount of sulphur, nitrogen and phosphor after total destruction of sample, sulphate-S is water soluble fraction (calculated from SO₄), and pyrite-S is calculated from the measured pyritic Fe.

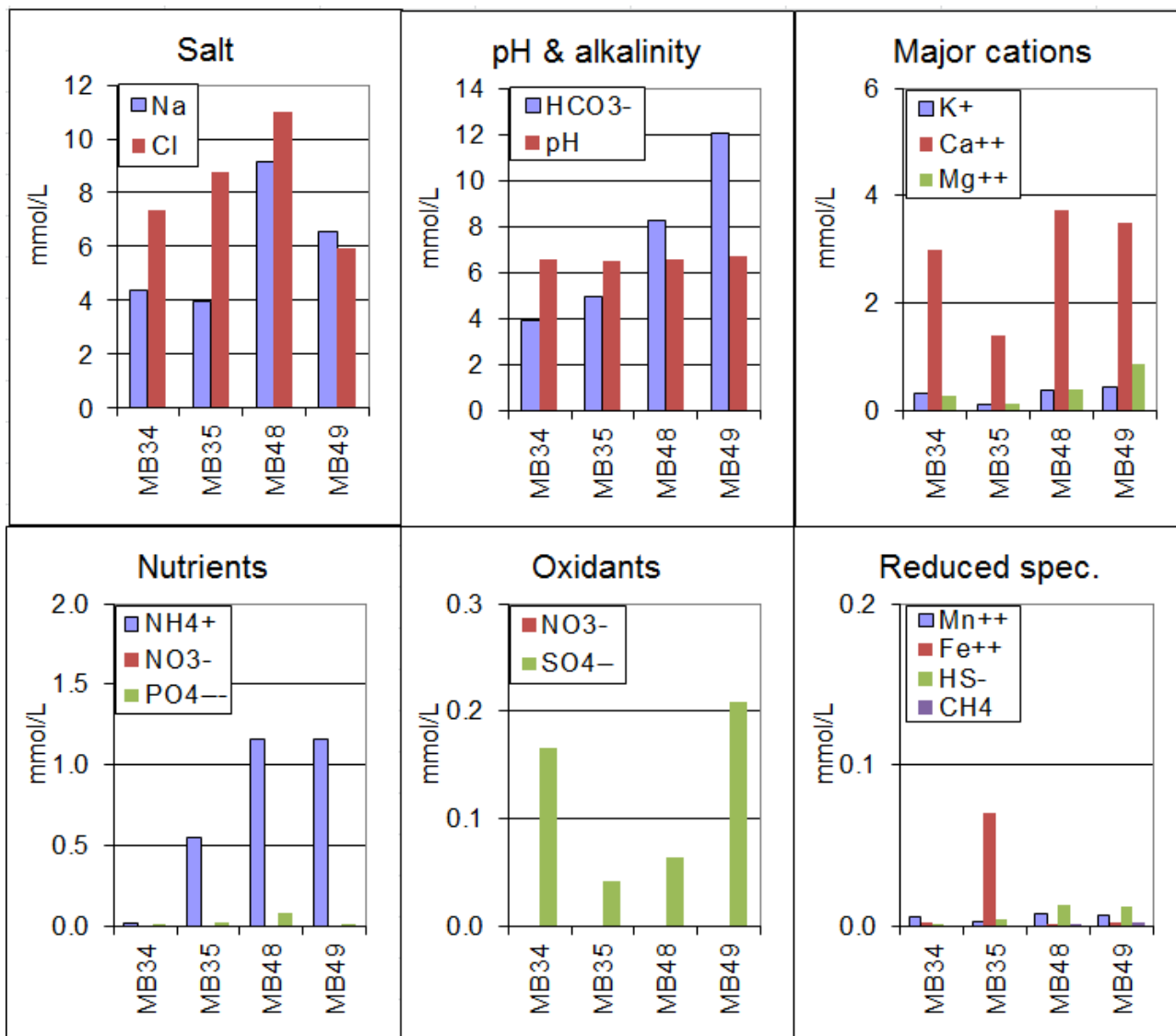


Figure 3: Results from analysis of groundwater taken from MB34, MB35, MB48 and MB49 on 16th of June 2014. Results for nitrate (NO₃⁻) were below the detection limit of the method (< 0.01 mmol/L). The samples were not analysed for oxygen.

Preservation conditions

The archaeological description of the two drillings showed that the archaeological deposits were in a lousy to poor state of preservation, with the only exceptions being the layers from -0.90 to -1.90 m asl in MB48, which were categorized as SOPS 3 (medium state). Regardless of the archaeological deposits being in a poor state of preservation, they are in general highly organic (Figure 2) and could therefore be susceptible to oxidation and subsidence. Figure 4 shows the oxygen consumption measurements that were made for all nine soil samples. As seen in Figure 4 the measured rates vary between 0.01 and 0.16 mg O₂/g dry soil/day, with a close relationship between the organic content (LOI) and the oxygen consumption rate. The rates measured in the samples from the two drillings are high compared to oxygen consumption results from samples from other parts of Bryggen (Figure 5). It is assumed that the main oxygen consumer is the organic material in the soil, although

some oxygen may also be used to oxidize different reduced inorganic species in the samples (such as reduced sulphur species from sulphate reduction). The high oxygen consumption rates show that most of the layers in MB48 and MB49 are very vulnerable to oxidation.

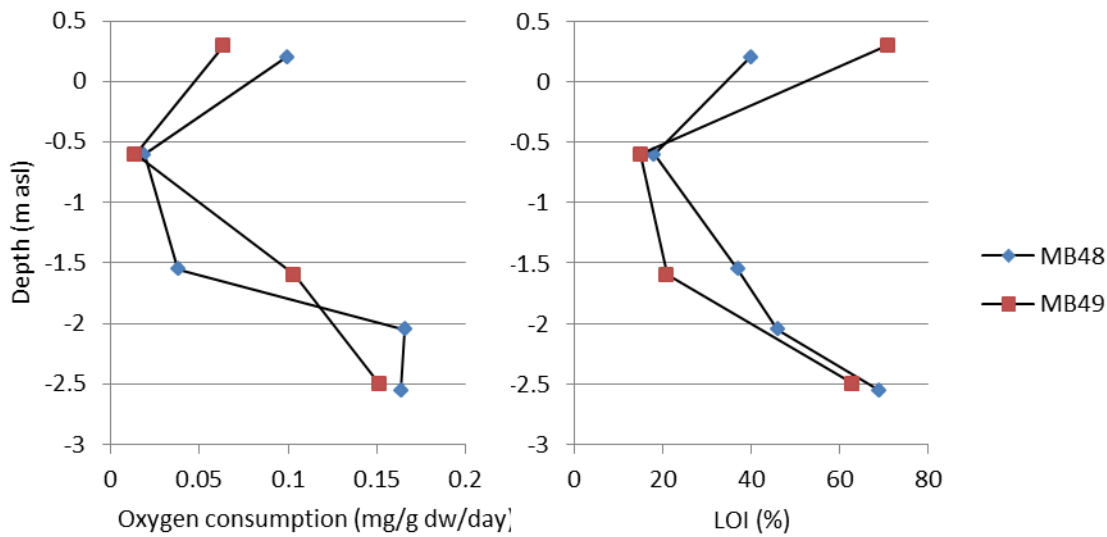


Figure 4: Left: results from the oxygen consumption measurements. Right: Loss on ignition.

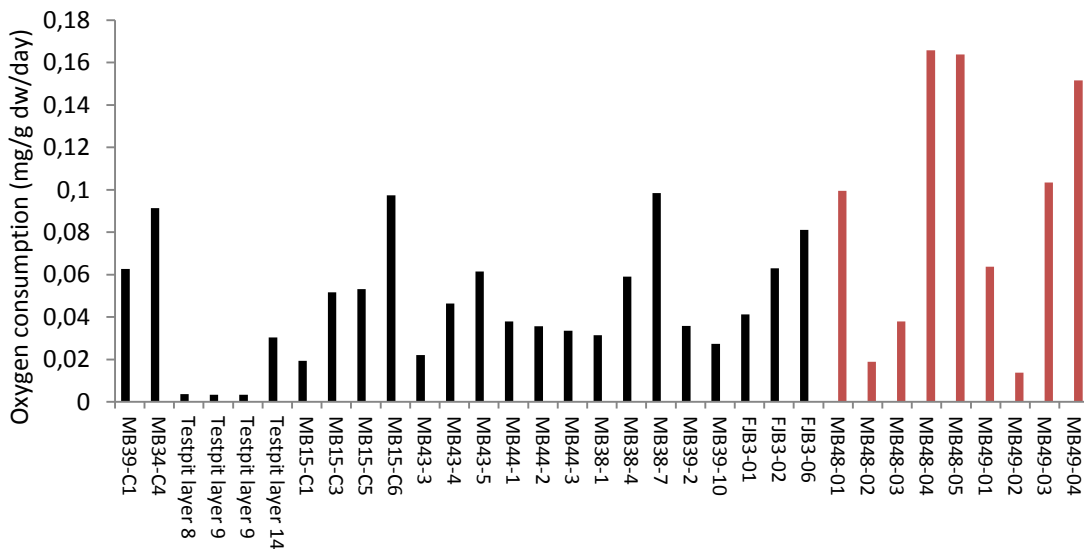


Figure 5: Oxygen consumption measurements at 5 °C made on samples from other locations at Bryggen (black) and on samples from MB48 and MB49 (red).

Continuous measurements of the groundwater level in both dipwells from May to October show levels in MB48 between 0.16 to 0.60 m asl (average 0.39 m asl) and in MB49 between -0.27 to +0.44 m asl (average 0.09 m asl) - Figure 6. This means that the upper highly organic layers are occasionally or frequently above the groundwater level, which is problematic considering the high reactivity of these layers. Furthermore, measurements show that temperatures in the two dipwells (Figure 7) are relatively high compared to soil temperatures measured in a test pit at the rear of Nordre Bredsgården at Bryggen (Matthiesen & Hollesen, 2011). This is probably due to heat from

the surrounding buildings. Currently the temperature measurements from MB48 and MB49 mainly cover the summer period. These measurements clearly indicate that the warming effect from the surrounding buildings could be even more pronounced during wintertime. Even small increases in soil temperature may have a significant influence on the decomposition of soil organic material. As shown in Hollesen and Matthiesen (2011) a temperature increase of 10 °C may increase the oxic decay rate by 100 to 180 %. The temperature level observed in the two dipwells until now is between 13-15 °C, which means that the oxic decay rates shown in Figure 5 (measured at 5 °C) may have to be doubled or even tripled. Future temperature measurements will help to elucidate this.

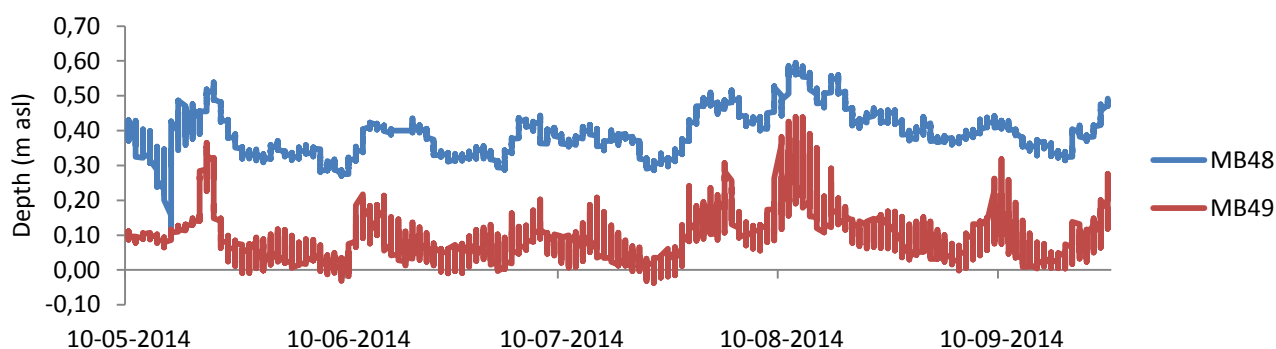


Figure 6: Measurements of the groundwater table in MB48 and MB49.

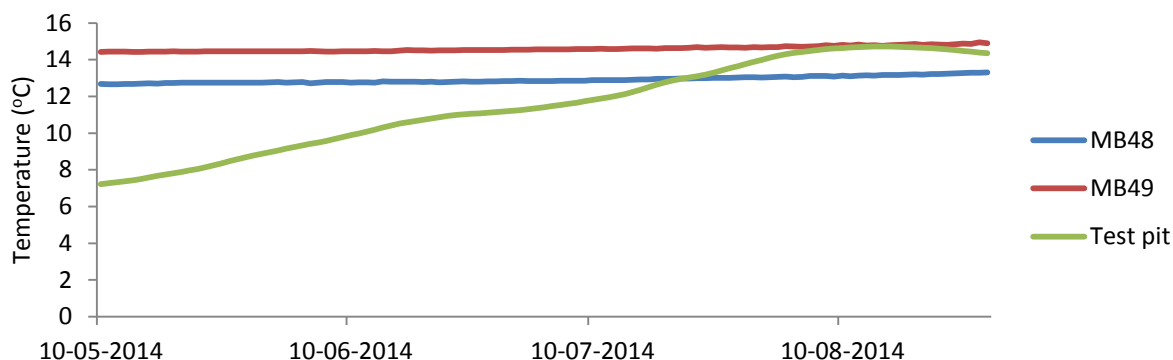
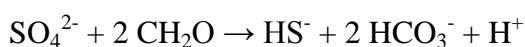


Figure 7: Measurements of temperature in MB48 and MB49 and soil temperature at 1.8 m depth in the test pit at the rear of Nordre Bredsgården, Bryggen.

Underneath the groundwater level, sulphate was the only oxidant present, and degradation by sulphate reduction is probably the main risk. The effect of sulphate reduction has already been discussed elsewhere (Matthiesen, 2010). Put very briefly, it is the process where sulphate is used by bacteria to oxidize organic material:



presented here as a complete oxidation of organic matter (shown as CH₂O) all the way to bicarbonate/carbon dioxide. Laboratory studies on material from Bryggen have demonstrated that sulphate is less reactive than other oxidants such as oxygen and nitrate, but the reactivity of sulphate

is still high enough to give a significant and unacceptable decay over time if there is a continuous sulphate supply to the deposits (Matthiesen et al, 2013). The oxidation rates of 4 different soil samples were measured to 0.002-0.008 mg CH₂O /g dry sample/day (at 15 °C).

Seawater contains both chloride and sulphate, at a fixed molar ratio of 0.052 SO₄:Cl (28 mmol/L SO₄ and 546 mmol/L Cl at a salinity of 35 ‰). This means that whenever seawater enters the groundwater, sulphate is added to the system along with the chloride. Figure 8 shows in more detail how water-soluble chloride (and sulphate) was distributed in the soil samples from MB48 and MB49, where the results have been recalculated to mmol/L using the water content of the samples. For comparison the content measured in the dipwells in June 2014 is shown as thick vertical lines, corresponding to the 1 m filter where groundwater can enter the dipwell.

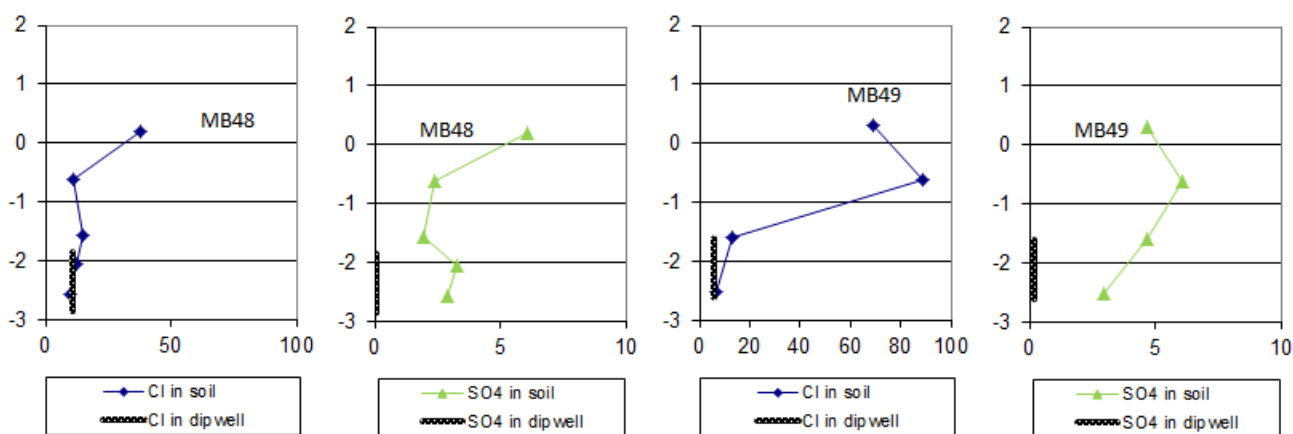


Figure 8: Measurements of water-soluble chloride and sulphate in soil samples from MB48 and MB49. Recalculated to mmol/L using the water content of the soil. The concentrations measured in groundwater from the dipwells are shown for comparison, using the length of the filter where groundwater enters the dipwell as “sample depth”.

Figure 8 demonstrates that the highest Cl (and sulphate) concentrations are found in the upper deposits of MB48 and MB49, with the highest Cl contents in MB49, which is situated nearer to the quayfront. This points towards an inflow of seawater to the upper layers, for instance during high tide. Lower Cl concentrations are found in the deeper deposits where the filter of the dipwells is placed, indicating that the seawater does not penetrate deep into the deposits.

There is a good correspondence between Cl measured in water samples from dipwells and measured in soil samples. On the other hand, the sulphate measured in dipwells is lower than what is measured in soil samples. This indicates that some of the sulphate in the soil is bound in solid particles. It cannot be excluded that the soil samples also contain some extra sulphate from oxidation of reduced sulphur species during transport and storage.

As for the dynamics of the system, it is too early to discuss this in detail, as groundwater samples have only been taken from dipwells MB48 and MB49 on one occasion. However, renewed sampling is planned every year in the period 2014-2018, making it possible to get some idea of the dynamics.

Over time, sulphate reduction leads to formation of sulphide, and parts of this sulphide will normally precipitate as acid-volatile sulphide or as pyrite, as already discussed in Matthiesen (2010). As with the other dipwells from the quayfront, the soil samples from MB48 and MB49 have low C/S ratios (between 5 and 18), which could indicate accumulation of reduced sulphur. The pyrite content has been measured in the deepest sample from MB48 and in two samples from MB49, showing contents of 15, 9 and 8 g pyrite-S per kg dry soil, which is a substantial percentage of the total sulphur in the soil (Figure 2). These deep layers were originally deposited in the harbour, and the accumulated pyrite represents both past and ongoing accumulation.

No investigation concerning the effect of temperature on sulphate reduction has been made at Bryggen, but literature data suggests that the temperature has a similar effect on anoxic decay as described above for oxic decay (Matthiesen et al. 2013, and references therein).

The decomposition of organic material may be accompanied by a heat production that can increase the soil temperature. Investigations by Hollesen et al. (2011b) show that heat production within a permafrost soil at Zackenberg in Greenland may slightly increase soil temperatures. Considering that archaeological deposits can produce 25 times more heat than the permafrost soil (Elberling et al., 2011) it is plausible that heat production could have a significant influence on soil temperatures and decomposition rates in the Bryggen deposits. Therefore, heat production rates should be measured to investigate whether or not this is the case.

Conclusions and future work

It has been shown that around dipwells MB48 and MB49:

- The upper soil layers are highly organic and periodically above the groundwater level. These layers are in a poor state of preservation. Oxygen consumption measurements show that they are highly reactive and thereby vulnerable to drainage.
- The deposits beneath the groundwater level are also highly organic and susceptible to decay. High contents of sulphur and pyrite in the soil indicate that some decay by sulphate reduction has taken place. The present-day decay rate for the deposits beneath the groundwater level depends on the supply of sulphate. Soil analysis indicates that sulphate is supplied to the upper deposits through seawater, but the dynamics are still largely unknown.

- Measurements of temperature in the dipwells indicate that soil temperatures beneath the Hanseatic Museum may be significantly increased by heat from surrounding buildings. This could increase decay rates, especially during the winter, and thereby be of great importance to the preservation conditions.

Further studies may include

- Yearly sampling of groundwater from the dipwells
- Logging of temperature in the soil, to get more information on heat influence from the Hanseatic Museum
- Logging of water and oxygen content in the unsaturated zone, to further elucidate the causes of the subsidence of the Hanseatic Museum
- A study of the “drying-out effect” whereby increased soil temperatures increase the evaporation of soil water and consequently increase the availability of oxygen
- A study of the heat production from decomposition of organic material from the deposits.

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Appendix 1

Results from analysis of soil samples from MB48 and MB49 (Eurofins)

Nationalmuseet, Brede
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2800 Kgs.Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00186234-01
Batchnr.: EUDKVE-00186234
Kundenr.: CA0000164
Modt. dato: 23.05.2014

Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB48-01(diesel)

Lab prøvenr:	18623401	Enhed	DL.	Metode	Um (%)
pH	8.0	pH		DS 287	
Tørstof	39	%	0.2	DS 204 mod.	10
Glødetab på tørstof	400000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	3200	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	8200	mg/kg ts.		Beregning	20
Phosphor, total	2500	mg/kg		Beregning	
Phosphor, total	6300	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	2100	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	910	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Metaller					
Svovl (S) total	11000	mg/kg ts.	50	SM 3120 ICP/OES	30

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Nationalmuseet, Brede
I.C.Modewegs Vej 1
2800 Kgs.Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00186234-01
Batchnr.: EUDKVE-00186234
Kundenr.: CA0000164
Modt. dato: 23.05.2014

Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB48-02(diesel)

Lab prøvenr:	18623402	Enhed	DL.	Metode	Um (%)
pH	8.0	pH		DS 287	
Tørstof	46	%	0.2	DS 204 mod.	10
Glødetab på tørstof	180000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	1200	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	2600	mg/kg ts.		Beregning	20
Phosphor, total	3300	mg/kg		Beregning	
Phosphor, total	7200	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	470	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	270	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Metaller					
Svovl (S) total	7600	mg/kg ts.	50	SM 3120 ICP/OES	30

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

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Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB48-03

Lab prøvenr:	18623403	Enhed	DL.	Metode	Um (%)
pH	8.0	pH		DS 287	
Tørstof	29	%	0.2	DS 204 mod.	10
Glødetab på tørstof	370000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	3700	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	13000	mg/kg ts.		Beregning	20
Phosphor, total	3500	mg/kg		Beregning	
Phosphor, total	12000	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	1300	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	460	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Metaller					
Svovl (S) total	14000	mg/kg ts.	50	SM 3120 ICP/OES	30

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Nationalmuseet, Brede
I.C.Modewegs Vej 1
2800 Kgs.Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00186234-01
Batchnr.: EUDKVE-00186234
Kundenr.: CA0000164
Modt. dato: 23.05.2014

Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB48-04

Lab prøvenr:	18623404	Enhed	DL.	Metode	Um (%)
pH	7.9	pH		DS 287	
Tørstof	35	%	0.2	DS 204 mod.	10
Glødetab på tørstof	460000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	2800	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	8000	mg/kg ts.		Beregning	20
Phosphor, total	3300	mg/kg		Beregning	
Phosphor, total	9300	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	810	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	580	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Metaller					
Svovl (S) total	19000	mg/kg ts.	50	SM 3120 ICP/OES	30

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Nationalmuseet, Brede
I.C.Modewegs Vej 1
2800 Kgs.Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00186234-01
Batchnr.: EUDKVE-00186234
Kundenr.: CA0000164
Modt. dato: 23.05.2014

Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB48-05

Lab prøvenr:	18623405	Enhed	DL.	Metode	Um (%)
pH	7.6	pH		DS 287	
Tørstof	23	%	0.2	DS 204 mod.	10
Glødetab på tørstof	690000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	2900	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	13000	mg/kg ts.		Beregning	20
Phosphor, total	1200	mg/kg		Beregning	
Phosphor, total	5100	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	1200	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	930	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Pyrit, FeS2	1.5	% ts.	0.01	* SM 3120 mod. ICP/OES	
Metaller					
Svovl (S) total	24000	mg/kg ts.	50	SM 3120 ICP/OES	30

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Nationalmuseet, Brede
I.C.Modewegs Vej 1
2800 Kgs.Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00186234-01
Batchnr.: EUDKVE-00186234
Kundenr.: CA0000164
Modt. dato: 23.05.2014

Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB49-01

Lab prøvenr:	18623406	Enhed	DL.	Metode	Um (%)
pH	6.9	pH		DS 287	
Tørstof	17	%	0.2	DS 204 mod.	10
Glødetab på tørstof	710000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	2300	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	14000	mg/kg ts.		Beregning	20
Phosphor, total	390	mg/kg		Beregning	
Phosphor, total	2300	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	12000	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	2200	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Metaller					
Svovl (S) total	20000	mg/kg ts.	50	SM 3120 ICP/OES	30

Tegnforklaring:

<: mindre end

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#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Nationalmuseet, Brede
I.C.Modewegs Vej 1
2800 Kgs.Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00186234-01
Batchnr.: EUDKVE-00186234
Kundenr.: CA0000164
Modt. dato: 23.05.2014

Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB49-02

Lab prøvenr:	18623407	Enhed	DL.	Metode	Um (%)
pH	7.0	pH		DS 287	
Tørstof	52	%	0.2	DS 204 mod.	10
Glødetab på tørstof	150000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	2100	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	4000	mg/kg ts.		Beregning	20
Phosphor, total	4200	mg/kg		Beregning	
Phosphor, total	8100	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	2900	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	540	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Pyrit, FeS2	0.93	% ts.	0.01	* SM 3120 mod. ICP/OES	
Metaller					
Svovl (S) total	7800	mg/kg ts.	50	SM 3120 ICP/OES	30

Tegnforklaring:

<: mindre end

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#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Nationalmuseet, Brede
I.C.Modewegs Vej 1
2800 Kgs.Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00186234-01
Batchnr.: EUDKVE-00186234
Kundenr.: CA0000164
Modt. dato: 23.05.2014

Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB49-03

Lab prøvenr:	18623408	Enhed	DL.	Metode	Um (%)
pH	7.9	pH		DS 287	
Tørstof	48	%	0.2	DS 204 mod.	10
Glødetab på tørstof	210000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	2400	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	5000	mg/kg ts.		Beregning	20
Phosphor, total	3600	mg/kg		Beregning	
Phosphor, total	7500	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	510	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	490	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Metaller					
Svovl (S) total	21000	mg/kg ts.	50	SM 3120 ICP/OES	30

Tegnforklaring:

<: mindre end

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#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Nationalmuseet, Brede
I.C.Modewegs Vej 1
2800 Kgs.Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00186234-01
Batchnr.: EUDKVE-00186234
Kundenr.: CA0000164
Modt. dato: 23.05.2014

Analyserapport

Sagsnr.: J. nr. 11031128
SagsNavn: Finnegård 1A, Bryggen
Prøve type: Jord
Udtagningsadresse: Bryggen MB48, MB49
Prøvetager: Rekvirenten
Prøvetagning:
Analyseperiode: 23.05.2014 - 17.06.2014

Prøvemærke: MB49-04

Lab prøvenr:	18623409	Enhed	DL.	Metode	Um (%)
pH	7.6	pH		DS 287	
Tørstof	25	%	0.2	DS 204 mod.	10
Glødetab på tørstof	630000	mg/kg ts.		DS 204	20
Uorganiske forbindelser					
Total Nitrogen	2900	mg/kg	5	Nordforsk 1975:6	20
Total Nitrogen	12000	mg/kg ts.		Beregning	20
Phosphor, total	2100	mg/kg		Beregning	
Phosphor, total	8500	mg/kg ts.	100	SM 3120 ICP/OES	30
Chlorid, vandopløselig	730	mg/kg ts.	5	* SM 17. udg. 4500-Cl (E)	20
Sulfat, vandopløselig	860	mg/kg ts.	1	* SM 17. udg. 4500-SO4 (E)	20
Pyrit, FeS2	0.81	% ts.	0.01	* SM 3120 mod. ICP/OES	
Metaller					
Svovl (S) total	19000	mg/kg ts.	50	SM 3120 ICP/OES	30

17.06.2014

Kundecenter
 Tlf: 70224267
 G30@eurofins.dk

Eurofins Miljø A/S
 Kundecenter

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

Appendix 2

Results from analysis of groundwater samples from MB34, MB35, MB48 and MB49, sampled on the 16th of June 2014.

**Nationalmuseet, Brede
 I.C. Modewegs Vej 1
 2800 Kgs. Lyngby
 Att.: Henning Matthiesen**
Rapportnr.: AR-14-CA-00194852-01
Batchnr.: EUDKVE-00194852
Kunde nr.: CA0000164
Modt. dato: 23.06.2014

Analyserapport

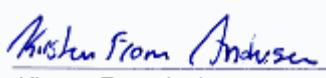
Prøvetype:	Grundvand						
Prøveudtagning:	16.06.2014 kl. 05:40						
Prøvetager:	Rekvirenten						
Analyseperiode:	23.06.2014 - 02.07.2014						
Prøvemærke:	MB 34						
Lab prøver:	80121126	Enhed	Kravværdier		DL.	Metode	Um (%)
			Min.	Max.			
pH	6.6	pH				DS 287	
Inddampningsrest	950	mg/l			10	DS 204	12
Konduktivitet (Ledningsevne)	120	mS/m			0.1	DS/EN 27888	10
Uorganiske forbindelser							
Ammonium	0.33	mg/l			0.006	SM 17. udg. 4500-NH3 (H)	10
Nitrat	< 0.5	mg/l			0.5	SM 17. udg. 4500-NO3 (H)	10
Orthophosphat-P	0.31	mg/l			0.005	SM 17. udg. 4500-P (F)	10
Chlorid	260	mg/l			1	SM 17. udg. 4500-Cl (E)	10
Sulfat	16	mg/l			0.5	SM 17. udg. 4500-SO4 (E)	10
Hydrogencarbonat	239	mg/l			2	DS/EN ISO 9963	10
Sulfid-S	0.06	mg/l			0.02	DS 278:1976 auto	28
Metaller							
Calcium (Ca)	120	mg/l			0.5	SM 3120 ICP/OES	30
Jern (Fe)	0.16	mg/l			0.01	SM 3120 ICP/OES	30
Kalium (K)	13	mg/l			0.2	SM 3120 ICP/OES	30
Magnesium (Mg)	7.0	mg/l			0.1	SM 3120 ICP/OES	30
Mangan (Mn)	0.32	mg/l			0.005	SM 3120 ICP/OES	30
Natrium (Na)	100	mg/l			0.1	SM 3120 ICP/OES	30
Kulbrinter							
Methan	< 0.005	mg/l			0.005	M 0066 GC/FID	38

Batchkommentar:

Sulfid resultatet skal tages med forbehold, da der var luft i flasken og kompleksbinder for gammel

02.07.2014

 Kundecenter
 Tel 70224256
 Rentvand@eurofins.dk


 Kirsten From Andersen
 Senior Kunderådgiver

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Nationalmuseet, Brede
I.C. Modewegs Vej 1
2800 Kgs. Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00194850-01
Batchnr.: EUDKVE-00194850
Kunde nr. CA0000164
Modt. dato: 23.06.2014

Analyserapport


Prøvetype:	Grundvand						
Prøveudtagning:	16.06.2014 kl. 05:55						
Prøvetager:	Rekvirenten						
Analyseperiode:	23.06.2014 - 02.07.2014						
Prøvemærke:	MB 35						
Lab prøver:	80121128	Enhed	Kravværdier		DL.	Metode	Um (%)
			Min.	Max.			
pH	6.5	pH				DS 287	
Inddampningsrest	540	mg/l			10	DS 204	12
Konduktivitet (Ledningsevne)	140	mS/m			0.1	DS/EN 27888	10
Uorganiske forbindelser							
Ammonium	10	mg/l			0.006	SM 17. udg. 4500-NH3 (H)	10
Nitrat	< 0.5	mg/l			0.5	SM 17. udg. 4500-NO3 (H)	10
Orthophosphat-P	0.64	mg/l			0.005	SM 17. udg. 4500-P (F)	10
Chlorid	310	mg/l			1	SM 17. udg. 4500-Cl (E)	10
Sulfat	4.0	mg/l			0.5	SM 17. udg. 4500-SO4 (E)	10
Hydrogencarbonat	304	mg/l			2	DS/EN ISO 9963	10
Sulfid-S	0.13	mg/l			0.02	DS 278:1976 auto	28
Metaller							
Calcium (Ca)	56	mg/l			0.5	SM 3120 ICP/OES	30
Jern (Fe)	3.9	mg/l			0.01	SM 3120 ICP/OES	30
Kalium (K)	4.4	mg/l			0.2	SM 3120 ICP/OES	30
Magnesium (Mg)	3.1	mg/l			0.1	SM 3120 ICP/OES	30
Mangan (Mn)	0.17	mg/l			0.005	SM 3120 ICP/OES	30
Natrium (Na)	91	mg/l			0.1	SM 3120 ICP/OES	30
Kulbrinter							
Methan	< 0.005	mg/l			0.005	M 0066 GC/FID	38

Batchkommentar:

Sulfid resultatet skal tages med forbehold, da der var luft i flasken og kompleksbinder for gammel

02.07.2014

Kundecenter
Tel 70224256
Rentvand@eurofins.dk


Kirsten From Andersen
Senior Kunderådgiver

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Prøvningsresultaterne gælder udelukkende for de(n) undersøgte prøve(r).

Rapporten må ikke gengives, undtagen i sin helhed, uden prøvningslaboratoriets skriftlige godkendelse.

**Nationalmuseet, Brede
 I.C. Modewegs Vej 1
 2800 Kgs. Lyngby
 Att.: Henning Matthiesen**
Rapportnr.: AR-14-CA-00194853-01
Batchnr.: EUDKVE-00194853
Kunde nr.: CA0000164
Modt. dato: 23.06.2014

Analyserapport


Prøvetype:	Grundvand						
Prøveudtagning:	16.06.2014 kl. 11:00						
Prøvetager:	Rekvirenten						
Analyseperiode:	23.06.2014 - 02.07.2014						
Prøvemærke:	MB 48						
Lab prøvenr:	80121125	Enhed	Kravværdier		DL.	Metode	Um (%)
			Min.	Max.			
pH	6.6	pH				DS 287	
Inddampningsrest	1200	mg/l			10	DS 204	12
Konduktivitet (Ledningsevne)	200	mS/m			0.1	DS/EN 27888	10
Uorganiske forbindelser							
Ammonium	21	mg/l			0.006	SM 17. udg. 4500-NH3 (H)	10
Nitrat	< 0.5	mg/l			0.5	SM 17. udg. 4500-NO3 (H)	10
Orthophosphat-P	2.7	mg/l			0.005	SM 17. udg. 4500-P (F)	10
Chlorid	390	mg/l			1	SM 17. udg. 4500-Cl (E)	10
Sulfat	6.2	mg/l			0.5	SM 17. udg. 4500-SO4 (E)	10
Hydrogencarbonat	506	mg/l			2	DS/EN ISO 9963	10
Sulfid-S	0.42	mg/l			0.02	DS 278:1976 auto	28
Metaller							
Calcium (Ca)	150	mg/l			0.5	SM 3120 ICP/OES	30
Jern (Fe)	0.076	mg/l			0.01	SM 3120 ICP/OES	30
Kalium (K)	15	mg/l			0.2	SM 3120 ICP/OES	30
Magnesium (Mg)	9.7	mg/l			0.1	SM 3120 ICP/OES	30
Mangan (Mn)	0.41	mg/l			0.005	SM 3120 ICP/OES	30
Natrium (Na)	210	mg/l			0.1	SM 3120 ICP/OES	30
Kulbrinter							
Methan	0.027	mg/l			0.005	M 0066 GC/FID	38

Batchkommentar:

Sulfid resultatet skal tages med forbehold, da der var luft i flasken og kompleksbinder for gammel

02.07.2014

 Kundecenter
 Tel 70224256
 Rentvand@eurofins.dk


 Kirsten From Andersen
 Senior Kunderådgiver

Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig

Nationalmuseet, Brede
I.C. Modewegs Vej 1
2800 Kgs. Lyngby
Att.: Henning Matthiesen

Rapportnr.: AR-14-CA-00194851-01
Batchnr.: EUDKVE-00194851
Kunde nr. CA0000164
Modt. dato: 23.06.2014

Analyserapport


Prøvetype:	Grundvand						
Prøveudtagning:	16.06.2014 kl. 10:30						
Prøvetager:	Rekvirenten						
Analyseperiode:	23.06.2014 - 02.07.2014						
Prøvemærke:	MB 49						
Lab prøvenr:	80121127	Enhed	Kravværdier		DL.	Metode	Um (%)
			Min.	Max.			
pH	6.7	pH				DS 287	
Inddampningsrest	940	mg/l			10	DS 204	12
Konduktivitet (Ledningsevne)	170	mS/m			0.1	DS/EN 27888	10
Uorganiske forbindelser							
Ammonium	21	mg/l			0.006	SM 17. udg. 4500-NH3 (H)	10
Nitrat	< 0.5	mg/l			0.5	SM 17. udg. 4500-NO3 (H)	10
Orthophosphat-P	0.36	mg/l			0.005	SM 17. udg. 4500-P (F)	10
Chlorid	210	mg/l			1	SM 17. udg. 4500-Cl (E)	10
Sulfat	20	mg/l			0.5	SM 17. udg. 4500-SO4 (E)	10
Hydrogencarbonat	734	mg/l			2	DS/EN ISO 9963	10
Sulfid-S	0.38	mg/l			0.02	DS 278:1976 auto	28
Metaller							
Calcium (Ca)	140	mg/l			0.5	SM 3120 ICP/OES	30
Jern (Fe)	0.14	mg/l			0.01	SM 3120 ICP/OES	30
Kalium (K)	17	mg/l			0.2	SM 3120 ICP/OES	30
Magnesium (Mg)	21	mg/l			0.1	SM 3120 ICP/OES	30
Mangan (Mn)	0.36	mg/l			0.005	SM 3120 ICP/OES	30
Natrium (Na)	150	mg/l			0.1	SM 3120 ICP/OES	30
Kulbrinter							
Methan	0.035	mg/l			0.005	M 0066 GC/FID	38

Batchkommentar:

Sulfid resultatet skal tages med forbehold, da der var luft i flasken og kompleksbinder for gammel

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Tegnforklaring:

<: mindre end

>: større end

#: ingen parametre er påvist

DL.: Detektionsgrænse

Um (%): Den ekspanderede måleusikkerhed Um er lig 2 x RSD%, se i øvrigt www.eurofins.dk, søgeord: Måleusikkerhed.

*): Ikke omfattet af akkrediteringen

i.p.: ikke påvist

i.m.: ikke målelig