Evaluation of Project report 2006N-001 by ExposMeter:

Oslo Fjord – Investigation of chemicals released from Malmøkalven dumping area - Polychlorinated biphenyls,

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Data sheet

Title:	Evaluation of Project report 2006N-001 by Expsometer Oslo Fjord - Investigation of chemicals released from Malmøkalven dumping area - Polychlorinated biphenyls
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1 Abstract

Excavated sediment from Oslo harbour has been dumped in the deep basin Malmøkalven since February 2005, and in March 2007 an investigation performed by ExposMeter for the Neptune foundation was published with the conclusions that chemicals were released from the dumping area. The Norwegian Pollution Control Authority asked The National Environmental Research Institute in Denmark to give an independent evaluation of the report in May 2007, to answer the question whether the conclusions of the report were backed up by the data presented.

Comments on the individual methods and results are given in chapter 3, and these comments form the base for the conclusions of the evaluation.

The conclusion of the evaluation is that the report is based on solid technical sampling and analysis of PCB concentrations in the water mass. However, given the sampling design, the data analysis performed, and lack of consideration to bottom topography and hydrological conditions, results from the report cannot be used on its own in order to conclude whether spreading of PCBs from the dumping site is occurring.

The chemical data could be used in conjunction with existing information of bottom topography, hydrology and other monitoring activities to assess the eventual spreading from the site.

2 Background

Oslo harbour started in February 2005 to excavate sediment around Pipervika, and the sediment was and is dumped in the deep basin Malmøkalven, all according to the permissions given by the authorities.

The Neptune foundation published in March 2007 an investigation of chemicals released from the dumping area that caused public concern. The investigation was performed by ExposMeter – Sampling technologies, and it concluded that contaminants spread out side the dumping area. However, there were uncertainties as to whether the conclusions of the report were backed up by the data presented. The National Environmental Research Institute in Denmark was therefore asked by the Norwegian Pollution Control Authority to give an independent evaluation of the report in May 2007.

2.1 Mandate for evaluation

The mandate for the evaluation given by the Norwegian Pollution Control Authority was to answer the follow questions:

- Are the conclusions on page 10 in the report well founded in the data acquired in the project?
- Do the data provide a base to evaluate if PCB is leaking out from the deposition area to other areas of the Bekkelagbasin?
- Is it shown that there is transport of PCB from the bottom of the deposition area to shallower depths, and thereby transported out of the area above the sill located at 30-40 ms depth? Should the report have commented on this?
- Do the data collected provide information on the eventual leakage of PCB from the quays at Pipervika before the excavation? Should the report comment on this?
- Are the hydrological conditions in the area described clearly and sufficiently, so that the issue of mechanism of spreading can be clarified?

The evaluation has only taken the methods and data presented in the report into consideration, no recalculations or data from other monitoring activities have been taken into account, as it was not included in the mandate given.

The main author, senior scientist Ingela Dahllöf, PhD, is responsible for the overall evaluation of the report, where co-authors Karin Gustafsson (Scientist, PhD) has contributed with oceanography expertise and Philipp Mayer (Senior scientist, PhD) has contributed to the evaluation of the sampling and analytical methods for PCBs.

3 Comments on the individual part of the report 2006N-001

3.1 Sampling design and supportive data

The sampling design consisted of placement of passive samplers for water (SPMDs) at different depths above the sediment surface in an area close to and around the dumping area in order to evaluate whether PCBs are spread outside the sampling area. Eighteen sampling sites were used and up to five depths at each site, during two sampling periods. In addition, SPMDs and water was sampled close to the excavation area. Salinity was also measured, although this is not described in the methods section.

Comment: The horizontal spatial coverage is well designed, but the choice to use depth above the sediment surface in stead of water depth makes the evaluation of the data difficult, especially as the bathometry is not described or taken into consideration. A summary table of sites and depths where data was actually retrieved would have been beneficial. No information on whether replication within sites was performed is given, although the variation between replicate samples including sampling, handling and analysis is stated to be 20%.

3.2 Sampling methodology and analysis of PCBs

The sampling of PCBs was performed using passive membrane samplers (SPMDs) that can measure the dissolved concentration of organic contaminants over a 21-day period. With the aid of performance reference compounds in the membranes, differences in sampling conditions that can affect the sampling rate can be corrected for, and using a factor the concentration can be recalculated to average water concentrations. The technique used for chemical analysis was GC-MS in an accredited procedure.

Comments: ExposMeter AB is one of Europe's leading laboratories for the passive sampling of organic contaminants within the marine environment, and they have substantial expertise in employment, handling and control of background contamination. The analytical technique is accredited and state-of-the art, and there are no reasons to question the quality of the measurements. However, dissolved water concentrations were determined by applying a "suitable factor" to the measured concentrations on the sampler, but the accuracy of these "suitable factors" is not addressed. Furthermore, it is not discussed whether these factors might be biased at high levels of dissolved organic carbon (DOC), colloids and/or small particles. It is important to note that the highest PCB concentrations were reported at the site of very high turbidity, and that recent research suggests that various water constituents can facilitate diffusive mass transfer. Therefore, the translation of measured concentrations on the sampler to the dissolved concentrations in the water appears to be the main source for error and uncertainty. With the information in

the report it is not possible to evaluate the accuracy of the applied factors, and it is not possible to evaluate their robustness at high turbidity.

3.3 Data presentation and statistical analysis

A multivariate statistical technique (Partial Least Square -PLS) was used to present the data in addition to the actual levels. The PLS consists of a Y-matrix with dependant variables and X-matrix with predictive variables, and an analysis where the regression between the predictive and the dependant variables is predicted. In this way, the significance of the relationship between for example sites and its PCB concentrations can be evaluated.

Comment: The methods section does not contain sufficient information on how the PLS-analysis was performed as no information is given on whether normalisation of the data was performed prior to analysis. It would have been helpful if the dependent and predictive variables had been presented. Although PLS is a strong multivariate technique, statistical analysis of for example similarities between different sites is weak.

3.4 Results

The results are first presented by giving the dissolved concentrations at each site and distances from the sediment for the two sampling periods, both as absolute values and as ranges at the different sites. Secondly, the multivariate analysis is used to present the similarities between the sites. A section on water mixing is also included.

The results from the water sample taken from the excavation site cannot be found in the report.

3.4.1 PCB amounts at different sites.

The sum concentrations of PCBs at each site and height above bottom are given, but it is not stated why some sites and depths are missing. The report refers to "PCB amounts", which is misleading. The passive sampling was directed at the determination of dissolved PCB concentrations, whereas exhaustive extractions are required in order to determine total concentrations of both free and bound PCBs, which then can be expressed as a PCB-amount.

For the first time period sites 4, 14 and 18 are missing, and for the second time period site 15 is missing. Several depths are missing at many of the sites but no reason is given although it is stated later on in the report that not all depths were sampled at each sites. Again, as commented on in the methods section, a summary table of sites and depths sampled would have been useful. Uncertainties are not included, although it is stated that a 20% variation is present between replicate samples.

There is a misprint in the text referring to Figure 7, where site 1 is wrongly cited as the site with the highest levels, when it should be site 2 as stated earlier in the text.

It is concluded in the report that concentration levels are similar between the two sampling occasions, apart from one site (site 2), which is in accordance with the data presented. No comments are made on the changes in concentration with depth at the different site, which is interesting especially as there are both decreases, increases, or no difference in concentration, with distance from the sediment. A more thorough analysis of changes in PCB concentration in the water column together with hydrological conditions and knowledge on general circulation could have given insight to spreading due to advection and mixing.

The total sum of the different congeners are also presented for the different sites, which shows that the PCBs at all sites come from a weathered source, and that site 13 could have a different origin. It could have been useful to present the data as % of different congeners within a site, as the absolute concentrations were given earlier. This would have facilitated a visual evaluation of the likeness of PCB fingerprints between sites and depth.

The isomer patterns of tetra-CB are given for the two sampling periods but it is not clear if or how this data is included in any other data analysis or the conclusions.

3.4.2 Mixing of water

Changes in salinity at different distances from the seafloor were used in the report to assess mixing. This approach is not appropriate for the evaluation of water mixing. There is no consideration taken to the bottom topography within the area, which means that data from for example 25 m above the seafloor can represent different water masses at different sites, as the depths at the different sites vary. If, for example, the sediment floor is at 70 m depth at one site and 30 m depth at another it is likely that the comparison is between two different water masses, and/or include sampling around a pycnocline which can induce large variation without describing mixing of water masses.

A discussion on advection and vertical mixing of water and substances could be performed based on knowledge of the general circulation in the area. To infer the general circulation, at least general hydrographic conditions (such as salinity with depth) and bottom topography are needed. Longer time series may also allow for a more conclusive evaluation of the general circulation and vertical mixing patterns. In the report, there is no information on the bottom topography. Salinity as measured during the field experiment is discussed, but only in relation to height above bottom.

It is not clear how Figure 14 should be interpreted. In the text it is stated that the darkest areas show the highest variation, whereas in the figure the terms 'Salinity Tot' and 'range' is given, which is confusing and could be interpreted as the average salinity and the variation around the average. The parameter shown and how it is derived should be explained in the text or Figure caption. The choice to provide detailed information of 25 m from the sediment floor, and not the other depths is not given. This is in some respect compensated for in Figure 15 that shows variation in salinity at different distances above the sediment floor, but again, this is hard to interpret as the different distances can

represent different depths. A better way to show the water properties during the field experiment would have been to display the salinity data as function of depth.

3.4.3 Concentrations on maps

In this section of the report the concentrations at different sites and distances from the seafloor are given in a more visually friendly manner to facilitate comparisons between sites and the different distances above the sediment floor. However, the scale of the dots used is inappropriate as the concentration interval differs between the dot sizes. For example do the two smallest dots represent a concentration range of ~100 pg/l, whereas the second largest dot represents a concentration range of ~ 450 pg/l. This means that two sites within a group can have larger differences in concentration that the differences between groups. Again, it has to be concluded that it would have been better to compare concentrations at the different water depths if transport from the site is to be evaluated. Furthermore, as no analysis of PCB concentrations in the sediments from the different sites were measured, it is hard to determine whether similar concentrations at 3 m above the sediment floor are due to spreading from the dumping site, or from contamination already present at the different sites.

3.4.4 PLS "finger printing"

The relationship in PCB contamination pattern between the sites was evaluated using PLS. Site 2 is excluded, which indicates that normalisation of the concentrations was not performed, although this is not stated in the report. If no normalisation was performed then the fingerprinting is based both of congener pattern and concentration, but with no consideration to as which factor had the strongest influence on the pattern. The loading plot, showing which congeners are responsible for the finger print, can not be used to assess whether concentration or congener pattern had the strongest influence on the finger print, as the concentrations of the congeners only are given as sums in the report. Site 5, at 3 m, period 1, is concluded to be the site most similar to site 1 where the dumped sediment originates from. Site 5 is also the site around the dumping area with the highest concentration. However, when taken the congener pattern shown in figure 10 into account, it can not be concluded that these two sites are more similar than compared to other sites, apart from sites 12 and 13. It should be pointed out that this is only a qualitative assessment as the figures are not so easy to read and interpret.

The use of a fingerprinting technique is appropriate in this report, but a more thorough evaluation should have been used. Had normalisation been performed on the data, then the sites could have been compared with respect to similarity of the sample from site 1. A technique using similarity matrices between samples based on Euclidean distances, and a permutation statistical approach, could have facilitated comparisons between sites with respect to origin of PCBs and thereby the spreading. Furthermore, the fingerprint at different depths within a site could also have revealed if there was an upward transport of PCBs that also could facilitate a horizontal spreading.

When comparing the two time periods it is evident that not all data were included as sites 4 and 14 are missing at the first time period, and site 15 at the second time point. This makes it difficult to assess how consistent the patterns are in time. In addition there is no comment on how consistently the different congeners are in describing the different samples. The only statistical evaluation performed is a 95% confidence interval indicated in the finger printing plots. Guidance on how this should be interpreted is not given, but an intuitive interpretation is that only samples from site 1 and 13 differ from the rest. It is stated that sites 3, 4, 5, 6 and 17 are the most similar to site 1, and it is likely that this forms the bases for the conclusions in the summary of the report.

3.4.5 Conclusions

Four conclusions are made in the report and are cited below:

1. Elevated levels of PCB are found outside the dumping area
2. The levels decrease with the distance from the dumping area
3. Elevated levels of PCB are found from bottom up to 40 meters above sea bottom to the dumping area
4. The PCB "fingerprint" close to dumping area resembles the pattern that was identified in Oslo harbour close to the excavating activities. Samples taken close to dumping area showed the closest agreement.

Comments on the conclusions:

1. Elevated levels can be said to have been found, if compared to the average concentration of the sites, excluding the harbour sites. It is however not clear how the comparison is made, and there is no information on previous water pollution at the different sites, which could have been provided using sediment samples.
2. There is no evidence for a decrease with distance to the dumping area either using the measurements closest to the sediment floor or higher up in the water mass, as the concentrations are either similar or lower in a non-gradient fashion.
3. Elevated concentrations can be said to have been found, but as the results provided are scares higher up in the water mass, and no reference in given as to how this comparison is made, or for which site(s), the conclusion can not indicate the cause for these elevated levels.
4. It is true that some of the sites closest to the dumping area had a similar finger print as from the harbour, but it is not clear what data the finger print is based on (congeners including concentrations or not). The same sites also had a close likeness to the other sites. The lack of information on data treatment, vertical resolution and likeness over time makes this conclusion questionable.

4 Conclusions of the evaluation

The conclusion of this evaluation is based on the comments and discussion in the previous section.

4.1 Answers to the questions in the mandate

- Are the conclusions on page 10 in the report well founded in the data acquired in the project?

Answer: No, the conclusions in the report are not well founded, as there is a lack of data evaluation that takes bottom topography and hydrological conditions into account.

- Do the data provide a base to evaluate if PCB is leaking out from the deposition area to other areas of the Bekkelagbasin?

Answer: The data provide a base to evaluate if PCB is leaking out from the deposition area, but these data should be combined with other existing data in a comprehensive evaluation in order to draw conclusions on whether the elevated PCB concentrations found originate from the Bekkelagbasin. The hydrological conditions are not taken into account, and because the finger printing analyses are not clear-cut, it is difficult to evaluate the source.

- Is it shown that there is transport of PCB from the bottom of the deposition area to shallower depths, and thereby transported out of the area above the sill located at 30-40 ms depth? Should the report have commented on this?

Answer: No, transport from the deposition area is not shown, and it is hard to make that evaluation as the bottom topography and hydrological conditions are not described. It would have been beneficial if the report had taken factors describing transport processes into account.

- Do the data collected provide information on the eventual leakage of PCB from the quays at Pipervika before the excavation? Should the report comment on this?

No, data was collected after the excavation was started. One indication of leakage from quays could be from the sample collected at Akers brugge (site 18). A comment would have been appropriate, but we do not know if this was a part of the instructions given to ExposMeter.

- Are the hydrological conditions in the area described clearly and sufficiently, so that the issue of mechanism of spreading can be clarified?

No, the hydrological conditions are not well described, which is needed in order to evaluate spreading. Bottom topography is not described, and as the sampling is described as distance from the sediment floor and not water depth, it is difficult to assess connection between the sites due to e.g. advection.

5 Recommendations

The authors of this evaluation would like to recommend that the data produced in the report is used together with available information on bottom topography and hydrological conditions in Oslo fjord. The chemical analysis are of high quality, and can together with an appropriate description of the dynamics of the Oslo fjord, be used for a more conclusive evaluation of eventual spreading of PCBs from the dumping area. We would also recommend that sediment samples from the sites are analysed, and that multivariate analysis is expanded in order to better pin-point the source(s).

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Clarification of the evaluation of project report: 2006N-001

NERI was today asked to clarify the some parts of the evaluation:

1) In the evaluation under 4.1 the following is stated:

- Do the data collected provide information on the eventual leakage of PCB from the quays at Pipervika before the excavation? Should the report comment on this?

Answer: No, data was collected after the excavation was started. One indication of leakage from quays could be from the sample collected at Akers brugge (site 18). A comment would have been appropriate, but we do not know if this was a part of the instructions given to ExposMeter.

The answer should read:
Answer: No, information on whether contamination from Pipervika, or from any other source, is affecting the measurements is not presented. As pointed out under the second bullet, the data analyses are not sufficient to pin-point the source of the contamination.

2) One question in the mandate was omitted by mistake and will be answered here:

- Are the figures in the report accurately reflecting the results in such a way that they cannot be misinterpreted?

Answer: The bars figures accurately reflect the results, but the maps where different sized dots are used to present levels can be misinterpreted, as the scale of the dots used is inappropriate as the concentration interval differs between the dot sizes. It is thereby difficult to determine whether gradients are present or not. The fingerprinting figures are correct, but difficult to interpret if the intention is to understand the source of contamination, especially as there is a lack of information on how the PLS analyses were constructed.

Under 3.3 the following statement is made:
Although PLS is a strong multivariate technique, statistical analysis of for example similarities between different sites is weak.

Clarification: This is a general statement regarding the PLS-technique. However, as it is a general trait it also concerns the data treatment in the report. Although sites can be "close" or "far away" from each other, the significance level of the separation between the sites can not be performed. A 95% interval is given in the score plots, and intuitively it would be interpreted such that samples within the circle are alike, and samples outside the circle are significantly different. As there is a lack of information of whether raw data or normalised data was used in the PLS, it is unclear if "likeness" between sites is due to concentration levels or the distribution of PCBs.

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