

1 Evaluation of factors affecting stakeholder risk
2 perception of contaminated sediment disposal in Oslo
3 harbour

4 *MAGNUS SPARREVIK*†, GERALD JAN ELLEN‡ AND MIKE DUIJN§*

5 * Norwegian Geotechnical institute, PO Box 3930 Ullevål Stadion, NO-0806 Oslo, Norway

6 magnus.sparrevik@ngi.no

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8 † Department of Industrial Economics and Technology Management. Norwegian University of
9 Technology, 7491 Trondheim, Norway ‡ Deltares, P.O.Box 85467, 3508 AL, Utrecht, The Netherlands

10 § TNO Built Science and Environment. P.O. Box 49 2600 AA, Delft, The Netherlands

11
12 **ABSTRACT**

13 The management of environmental pollution has changed considerably since the growth of
14 environmental awareness in the late sixties. The general increased environmental concern and
15 involvement of stakeholders in today's environmental issues may enhance the need to consider risk in a
16 much broader social context rather than just as an estimate of ecological hazard. Risk perception and the
17 constructs and images of risks held by stakeholders and society are important items to address in the
18 management of environmental projects, including the management of contaminated sediments.

19 Here we present a retrospective case study that evaluates factors affecting stakeholder risk perception
20 of contaminated sediment disposal that occurred during a remediation project in Oslo harbour, Norway.
21 The choice to dispose dredged contaminated sediments in a confined aquatic disposal (CAD) site rather
22 than at a land disposal site has received a lot of societal attention, attracted large media coverage and
23 caused many public discussions. A mixed method approach is used to investigate how risk perceptive
24 affective factors (PAF), socio-demographic aspects and participatory aspects have influenced the various
25 stakeholders' preferences for the two different disposal options.

26 Risk perceptive factors such as *transparency* in the decision making process and *controllability* of the
27 disposal options have been identified as important for risk perception. The results of the study also
28 supports the view that there is no sharp distinction in risk perception between experts and other parties
29 and emphasizes the importance of addressing risk perceptive affective factors in similar environmental
30 decision making processes. Indeed, PAFs such as transparency, openness and information are
31 fundamental to address in sensitive environmental decisions, such as sediment disposal alternatives, in
32 order to progress to more technical questions such as the controllability and safety.

33 **Introduction**

34 The rapid rise of environmentalism in response to problems caused by pollution, particularly since the
35 late sixties, has had a considerable impact on how environmental policy issues and mitigating measures
36 are handled (1-3). Briefly, roughly from the early 1970s there was increasing recognition amongst the
37 public that simply diluting and dispersing environmental contamination was not sufficient or acceptable.
38 Thus, solutions to prevent emissions in the atmosphere and in water were introduced and heavily
39 imposed with regulations and legislative actions. From this stage the policies have evolved, and broader
40 interest groups play direct or indirect roles in environmental policy making, as environmental issues
41 have steadily become an increasing public concern.

42 Policy development for the management of contaminated sediments has lagged behind development in
43 other areas. Part of this is related to the ambiguous nature of regulating polluted sediments. Many sites
44 are contaminated from previous activities ("old sins") and by diverse pollution sources, making it

45 unclear who bears the burden of blame or remediation. Contaminated sediments are therefore still
46 generally managed through a strong post-pollution regulative focus similar to the early stages of
47 environmental policy (4), rather than through a preventative focus. In Norway and some other countries,
48 however, the awareness of preventive measures has grown, and precautionary ecological risk
49 assessments, which are used to identify, characterize and quantify environmental hazards, has been
50 advocated (5).

51 As with other environmental issues, the involvement of the public in sediment management has
52 become more evident and should be addressed. Owing to such involvement it is necessary to consider
53 risk assessment and management in a much broader context than earlier (6). Whereas ecological risk
54 assessments evaluate hazards from contaminated sediments to be related to toxic effects for humans and
55 the ecosystem, certain members of society may use a more intuitive assessment of the risk involved. The
56 distinction between this statistically estimated risk and public acceptability was early identified and
57 addressed as risk perception (7). Previous research has documented that risk perception may differ
58 significantly from statistical estimations and is affected by social acceptability (8). Later research has
59 nuanced this view, suggesting that risk perception depends both on rational and more intuitive
60 arguments (9).

61 Suggestions on how to address risk in public management ranges from scientific concepts trying to
62 influence and alter risk perceptions via communication and education using scientific risk assessments
63 (10), to the more pragmatic approach where the scientific results from risk assessments competes with
64 the outcome from participatory processes (11). Other intermediate viewpoints where risk perception is
65 addressed, evaluated and taken into account in the management process by experts and decision makers
66 are also referred to in literature (12).

67 The gap in risk perception between different parties in the management process may, according to
68 empirical research, only be bridged through communication and involvement, and by placing the same
69 emphasis on lay perception as is placed on technical knowledge (13). On the other hand, diversity in risk
70 perception may also be an asset since it avoids concealing important hazards. Examples of such

71 behaviour was found in the Former Soviet Union were unwanted hazards were regularly concealed (14).
72 Complete consensus may therefore be both unrealistic and in many cases unwanted.

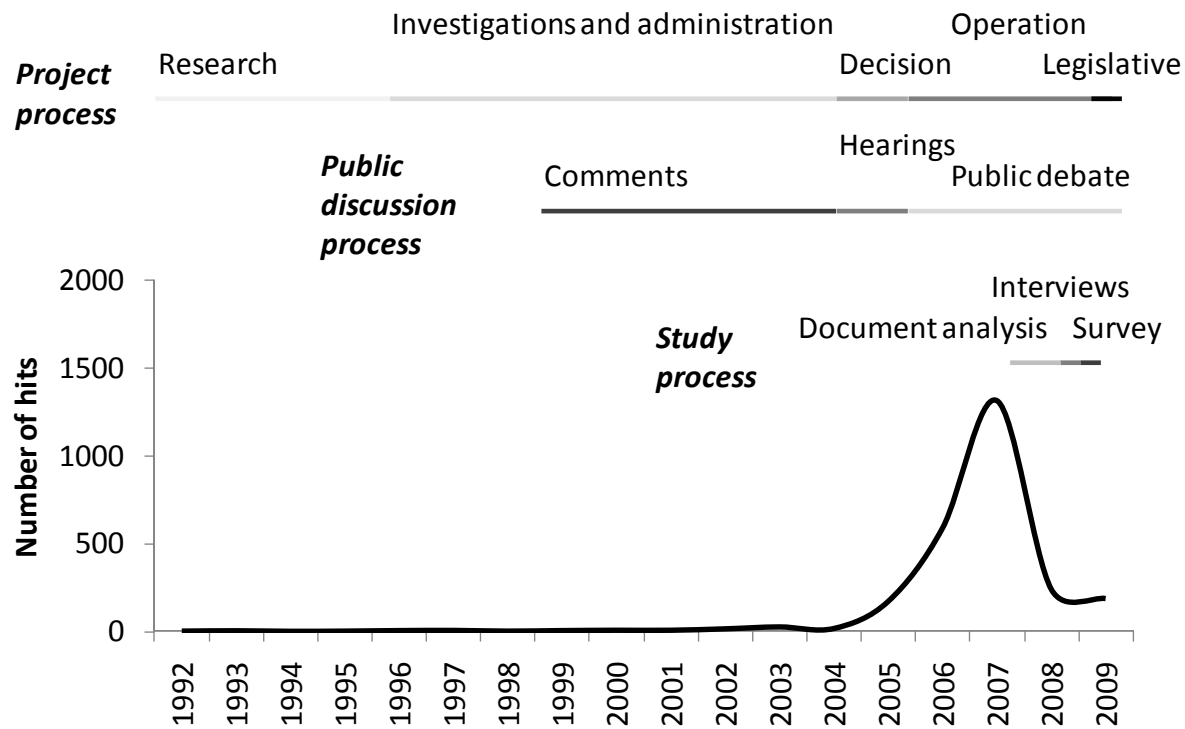
73 In this paper we use a contaminated sediment remediation project in Oslo harbour Norway, which has
74 been subjected to substantial social involvement, as a study object to investigate the possible effect of
75 risk perception in the choice of alternative disposal solutions for contaminated sediments. Our study is
76 part of a larger research project aiming to assess methods for improved stakeholder involvement in
77 contaminated sediment management (15). The main aim of this retrospective study is to assess whether
78 it is possible to identify risk perceptive factors among the involved participants and to investigate *how*
79 and *why* these factors have affected the view on the disposal alternatives. An additional aim is to
80 identify how risk perception is encompassed in a societal context (16). The results herein provide useful
81 recommendations for future stakeholder involvement processes in contaminant sediment management.

82 **Materials and Methods**

83 Study object

84 A major sediment remediation project was conducted in Oslo harbour, Norway, during the period
85 1992-2009. Navigational requirements, urban development and environmental concern initiated the
86 dredging of approximately 300.000 m³ of contaminated sediments in the inner harbour area. One of the
87 major issues in the project was related to the disposal of this contaminated sediment after dredging. Two
88 principally different solutions were evaluated during the planning phase. One solution involved the
89 transportation of the dredged material on barges to a land disposal site, situated approximately 80 km
90 from the harbour. This site, NOAH Langøya, is a national disposal facility for hazardous waste. The
91 second option was to construct a confined aquatic disposal site (CAD) at Malmøykalven. This site, a 70
92 meter deep sea-basin 3 km from the dredging area, has previously been used for uncontrolled disposal of
93 dredged material.

94 During the long history of the different project phases public interest and discussion topics changed,
95 as indicated in Figure 1.



96

97 Figure 1 Overview of the project and related public discussion process as measured by number of
 98 materials published in Norwegian published media (television, radio, the Web and newspapers) found in
 99 the Retriever® database (www.retriever-info-com) using the search word “Malmøykalven”

100 The project process started with “research” period that assessed the potential consequences of
 101 contaminated sediments to people and environment. This period was followed by a sediment
 102 “investigation and administration” period to map the present situation and to come up with potential
 103 remedial solutions. Assessing the feasibility of using the CAD at Malmøykalven was an important
 104 activity during this phase. Both the use of the CAD and transport to the site with barges were subjected
 105 to an environmental impact assessment (EIA). The proposed solution was evaluated against a no-
 106 remediation scenario and was found to be feasible. Alternative disposal solutions were only briefly
 107 discussed in the EIA. After several political delays, the need to find a solution became urgent in 2004
 108 due to urban development in the harbour area and the construction of a submerged road tunnel. During
 109 the brief “decision” phase a development plan was produced and a formal decision process was initiated.
 110 This process was finalized in 2005 and resulted in the decision to start the dredging activities

111 immediately and to use the CAD as a disposal solution. The operation started early in 2006 and
112 continued until mid 2009 during the “operation” phase.

113 Simultaneously to this project process a public discussion process was initiated. This began with a
114 “comment” period, and involved receiving comments to the EIA from the public during the period
115 1999-2003. In the “hearings” period of 2004-2006 the plan for development and remediation of the area
116 were subjected to formal hearings and public meetings were conducted. As illustrated in Figure 1, media
117 interest in the project started to increase during this period. This suggests how the project started to be
118 associated with perceptive values that were socially amplified through media interest. This pattern of
119 increased media interest during public discussions corresponds to findings from other projects (17).
120 During the operation period , the remediation project received substantial societal attention such as civil
121 disobedience actions, protests campaigns and public debate, referred to as the “public debate” phase,
122 most of which were directed towards the chosen remediation operation and the environmental
123 monitoring of the process. As seen in Figure 1, the debate also dramatically influenced media coverage.

124 Data collection

125 Data was collected to reflect the views of the stakeholders involved in the project rather than the
126 general public opinion. Stakeholders are defined here as people, organisations or groups who are
127 affected by the issue and who have the power to make, support or oppose the decision or who have the
128 opportunity to provide relevant knowledge to the decision making process (18).

129 This research is based on the case study method by Yin (19) with a mixed method approach to
130 combine the strength of quantitative and qualitative investigation methods (20). In this study, interviews
131 and analysis of documents are used as support for a survey, which presented below. This was conducted
132 during the later stages of the operation and public debate period (see Figure 1). Triangulation of results
133 is performed using the validating quantitative data model (20). In this model, the quantitative results and
134 conclusions from the survey are validated with qualitative data by using results from the interviews. The
135 idea to base risk perceptive research primarily on quantitative data is advocated by Sjöberg (21), who

136 emphasised the need to simplify the interpretation by singling out dominating and important themes by
137 use of statistical methods (21).

138 The data collection started with a qualitative review of project-relevant documents and materials as
139 scientific reports and official correspondences. Through use of this material, stakeholders that had been
140 active in the decision making process were identified and on this basis a list of stakeholders consisting
141 of 160 people and organisations was established.

142 From this list, a subset of 33 key stakeholders was selected. The key stakeholders were presumed to be
143 the most *influential* and *interested* persons in the process, based on the following definitions. *Influence*
144 was defined as the potential to affect the process either through formal legislative rights or by informal
145 mobilisation through media and financial instruments. *Interest* was defined by the potential level of
146 benefits or losses the stakeholder could experience from the process. Like influence, interest was
147 categorized into formal interests such as regulative issues and informal interests such as gain or loss of
148 image and popularity. In-depth interviews were conducted with 23 key stakeholders during the autumn
149 of 2008 (67% participation). No particular pattern of reasons for not participating in the study was
150 evident during the process. Interviews were performed in the stakeholders' environment or in a neutral
151 place and were based on a questionnaire that was distributed before the interviews; see supporting
152 information (SI) pages S4-S8. Stakeholders were interviewed anonymously due to the degree of conflict
153 in the project. The questions were mainly open ended to facilitate discussion with the key stakeholders.

154 To confirm and support the main conclusions from the interviews an anonymous web survey with
155 closed questions relating to the above mentioned topics was conducted during the winter 2009.
156 Questions are presented in SI pages S9-S14. Recruitment to the survey was based on the original
157 stakeholder list of 160 people, omitting interviewed key stakeholders and people without valid e-mail
158 addresses. This resulted in a list of 92 names. In addition, interviewed key stakeholders were submitted
159 an e-mail with the link to the survey with a request to forward the survey to persons they considered
160 suitable. The survey included questions that were tailored to identify and exclude responses not relevant
161 to the proposed stakeholder population definition. The survey received 87 valid responses within a time

162 period of 44 days, whereof 49% were directly recruited parties and 51% were forwarded answers. The
 163 response rate among the recruited was 50%. The answers consisted of 29% female and 71% male
 164 responses. The majority of the respondents (55%) were between 41-65 years old. Sixty-five percent of
 165 the respondents lived in Oslo, but people living in the vicinity of the disposal site were also represented,
 166 (23%). The vast majority of the respondents (94%) had university education (Bachelor, Master or PhD).

167 Identification of risk perceptive factors and their relationship

168 One of the ways that risk tolerance can be related to particular situations are through perception
 169 affecting factors (PAFs) (22). These generic factors were initially developed in order to estimate
 170 perceptive risk for natural hazards, but may after adoption also be used as a basis for defining PAF
 171 related to risk perception of the CAD in the Oslo harbour project, Table 1.

172 Table 1 Overview of generic and project specific affecting factors (PAF) influencing perceptions of
 173 risk¹.

| Generic perception affecting factors | Potential project perception affecting factors |
|--------------------------------------|---|
| Voluntariness | Risk attitude |
| Knowledge | Degree of involvement General confidence Information about the process Transparency and independence Objectives for choice of disposal solution |
| Endangerment | Controllability of the solution Environmental effect |
| Reducibility | Usability of fjord and disposal area after remediation |

174 1 Adapted from (22)
 175

176 The four main PAFs summarised in Table 1 are voluntariness, knowledge, endangerment and
 177 reducibility. *Voluntariness* relates to the risk attitude of people and the willingness to take risks.
 178 *Knowledge* incorporates a broad spectrum of items relating to information, general confidence,
 179 involvement and transparency as well as formulations of objectives. *Endangerment* incorporates the

180 question on how the risk may affect humans and the environment, either negatively or positively.
181 Finally, the *reducibility* relates to possible negative considerations associated with use.

182 Statistical analyses, described below, was conducted to assess whether it was possible, based on the
183 survey data material, to identify and relate any of the PAFs to the perceived risk of the CAD. The study
184 used exploratory factor analysis based on the principal component method (PCA) to identify underlying
185 factors based on the survey model questions. PCA as well as subsequent analyses of variance (ANOVA)
186 and reliability testing was performed using the statistical package SPSS 17.0. (23).

187 Structural equation modelling (SEM), normally used in psychological research, was used to identify
188 structural relationship between the identified factors. SEM combines factor analysis and multiple
189 regression in one operation using model fit indicators to validate the proposed models (24). Unlike PCA,
190 which explores the structural relationship between an infinite set of parameters, SEM confirms or rejects
191 a proposed model structure based on a given set of input parameters. The software package AMOS 7.0
192 (25) was used for the SEM modelling.

193 The statistical modelling consisted of five parts. *The first part* identified PAFs in the data material
194 from the survey by using a two stage explorative factor analysis procedure (26). The procedure started
195 by using all measured linear scaled model questions from the survey to identify underlying patterns in
196 the data material and to select which model questions should be retained in subsequent analysis. To
197 maintain sufficient statistical power in the data material, missing values were replaced using the
198 expectation-maximization (EM) method, SI Table S1. EM uses a recommended iterative algorithm to
199 estimate missing values based on the entered data material (27). A theoretical framework for the model
200 question selection is presented in SI page S16.

201 The factor analysis was then repeated using the retained model questions. The mean factor scores of
202 the latent factors were used for further assessment and statistical testing. The results were triangulated
203 against the results from the interviews.

204 *The second part* of the statistical work investigated the correlation between the identified PAF and the
205 perceived risk related to the CAD. The question about perceived risk had been included in the survey as

206 a separate model question. This investigation of correlation was performed using a linear regression
207 model with risk perception as the dependent variable (DV) and the identified PAFs as independent
208 variables (IV). Only IV's with significant correlation to perceived risk of the CAD were retained for
209 subsequent analysis.

210 *The third* part of the modelling involved a sensitivity analysis of the results. Since some weaker model
211 questions and factors had been discarded, it was essential to perform a sensitivity analysis on the
212 discarded model questions to assess whether the procedure of model question selection had the potential
213 to bias the results.

214 *The fourth part* used SEM to test different structural models assuming that a relation existed between
215 perceived risk of the CAD as a dependent variable and the significantly correlated PAFs identified in the
216 second part. The structural models were validated against a model with no structural relationship.

217 *In the fifth* and last part of the statistical analysis, the perceived risk related to the identified PAFs was
218 correlated to the preferential disposal solutions of the respondents (the selected aquatic disposal or the
219 alternative land disposal solution) and was analysed using a one-way ANOVA. The same method was
220 also used to assess whether socio-demographic and participatory aspects were important for the outcome
221 of the process.

222 The outcome of the statistical analysis was used to conclude on what implications risk perception may
223 have on future disposal projects.

224 **Results and Discussion**

225 Determining perceptive affecting factors

226 The two stage exploratory factor analysis procedure described above substantially reduced the number
227 of model questions retained for analysis and gave a proposed structure of four latent factors in the data
228 material (SI Figure S4). Table 2 shows the results of the factor analysis. The factor loadings given in the
229 figure express how well the model questions correlate with each other. The four retained factors shown
230 in the table explained 75% of the variance in the data material (SI Table S6). In order to evaluate the
231 reliability of each factor, Cronbach alpha, α , which is a reliability indicator for sampling consistency

232 (28) was measured. The values ranged from 0.68 to 0.77, where a value above 0.70 is normally
 233 considered to be acceptable (29).

234 Table 2 Factor loadings and Cronbach alpha scores, α , for the model questions relating to project
 235 specific PAFs. Absolute values greater than 0.5 are considered to be correlated

| Model question | Factor analysis results for the project specific perceptive affecting factors (PAF) ^c | | | | |
|--|---|-----------------------------|--------------------------------|---------------------------|-------------------|
| | N ^a | Controll- ability | Worka- bility objectives | Health-Env. objectives | Transpar- ency |
| | | α ^b =0.77 | α =0.72 | α =0.74 | α =0.68 |
| Added value in addition to environmental effect (scale 1-5) | 76 | -0.16 | 0.87 | 0.07 | 0.05 |
| Importance of local solution (scale 1-5) | 77 | -0.16 | 0.87 | 0.07 | 0.05 |
| Reduced human risk (scale 1-5) | 77 | 0.09 | 0.07 | 0.88 | -0.16 |
| Reduced marine risk (scale 1-5) | 78 | -0.07 | -0.05 | 0.88 | 0.15 |
| Sufficient time for decision making (scale 1-5) | 83 | 0.15 | -0.004 | 0.21 | 0.72 |
| All research material accessible (scale 1-5) | 85 | 0.01 | 0.02 | -0.10 | 0.90 |
| Perceived risk of sediments upon project termination (scale 1-3) | 81 | 0.88 | -0.04 | -0.02 | -0.10 |
| Spreading of contamination from the CAD (scale 1-3) | 80 | -0.79 | -0.07 | -0.03 | 0.04 |
| Future effect of CAD on the fjord (scale 1-5) | 82 | -0.72 | 0.11 | -0.08 | -0.19 |
| Effect of CAD on future fish/shellf. cons. (scale 1-5) | 55 | 0.72 | 0.03 | -0.01 | 0.25 |

236 ^a Number of respondents before missing value replacement

237 ^b Cronbach alpha reliability value. A value above 0.70 is normally considered to be acceptable (29).

238 ^c Expressed as factor loadings ranging from 0 to ± 1 . Factor loadings above 0.5 or below -0.5 are
 239 shown in bold

240 The first PAF *controllability* incorporates perceived effect, spreading of contaminants, potential
 241 change in future consumption patterns and perception of sediment risk after project execution. This PAF
 242 incorporates both endangerment and reducibility, which were not possible to distinguish between in the
 243 analysis. The second and third PAF, *workability* and *health-environmental objectives*, respectively,

244 relate to stakeholders' objectives when selecting the preferred disposal solution. The analysis clearly
 245 distinguishes between reduction in human and environmental risk by using the preferred solution and
 246 objectives related to the workability of the solution, such as the importance of handling contaminated
 247 sediments locally and the importance of an added value other than reduction of environmental risk. The
 248 fourth PAF *transparency*, also relates to knowledge, and specifically to transparency in the decision
 249 making process with emphasis on accessibility and sufficient time to involve stakeholders in the
 250 decision.

251 The identified PAFs based on the results of the web survey, presented Table 2 are consistent with
 252 results from the in depth interviews presented in Table 3, as will be elaborated below.

253 Table 3 Arguments, relating to determined PAF, assessed as important by the interviewed key
 254 stakeholders.

| Identified PAF | Arguments in interview responses | Response rate (%) |
|-------------------------------------|--|-------------------|
| Controllability | Different risk for aquatic disposal compared to other solutions. | 77 |
| Workability objectives | Importance of cost, safety and performance for the decision on solution | 81 |
| Health and environmental objectives | Importance of human risk reduction, environmental risk, contaminant transportation | 77 |
| Transparency | Open discussion | 4 |
| | Information/communication | 50 |
| | Public decision making | 13 |
| | Involvement | 32 |
| | Independent control | 14 |

255
 256 A majority of the interview respondents felt that aquatic disposal had a different risk than other
 257 solutions and mentioned different arguments related to controllability, including chemical stability,

258 spreading of contaminants during disposal, weather and stream conditions as well as long term effects as
259 important in risk assessment.

260 Approximately 80% of the stakeholders interviewed mentioned health and environmentally related
261 objectives (reduced contaminant transportation, reduced bioavailability etc.) and workability objectives
262 (cost efficiency, safety, performance) as important objectives in the choice of preferred disposal
263 solution.

264 As to transparency a number of items relating to participation, such as information/communication,
265 involvement, public decision making and independence, were mentioned as important items in the
266 decision making process. This observation was more pronounced in the interview results compared to
267 the survey results which merely concluded on transparency as one of several PAFs potentially affecting
268 perceived risk.

269 PAFs vs. risk perception

270 The relationship between the identified PAFs and perceived risk of the CAD, which had been
271 measured directly as an interval scaled variable, was determined through a multiple regression analysis
272 using risk perception as the dependent variable (DV) and the identified factors as independent variables
273 (IV). The results of a t-test showed significant correlation for *controllability* ($t=2.13$; $p<0.05$) and
274 *transparency* ($t=-4.56$; $p<0.05$) against perceived risk, whereas *health-environmental objectives* and
275 *workability objectives* were found to be uncorrelated ($t=-1.03$; $p=0.30$ and $t=-1.47$; $p=0.14$ respectively)
276 with this variable.

277 Sensitivity analysis

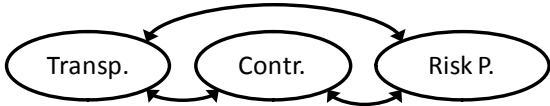


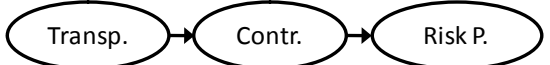
278 One important item in the PAF factor analysis is outcome sensitivity with respect to the model
279 questions selected. The study represents a substantial sample of the population, which is satisfactory. On
280 the other hand the sample material is limited and has been subjected to a missing value analysis, which
281 may reduce the statistical reliability. A sensitivity analysis performed using a modified approach that
282 included additional factors that had initially been discarded did not identify additional dependent
283 variables compared to the initial solution (see SI Table S12). The results from this modified approach

284 showed that *controllability* was still correlated to perceived risk when more model questions were
 285 included, whereas *transparency* was no longer correlated (SI Table S14). In an ideal situation the web
 286 survey should have been altered and repeated for the ambiguous model questions. However, due to the
 287 sensitivity of the project, the web survey was performed anonymously and was conducted in an on-going
 288 project process and could therefore not be repeated. Since the results from the interviews confirmed the
 289 survey results the initial approach was retained.

290 Structural relationship

291 The possibility of a structural relationship between the PAFs *controllability* and *transparency* with
 292 remediation solution was identified using different structural relationship models.

293 Table 4 Statistical analysis (SEM) of the structural relationship between the PAFs transparency
 294 and controllability, with risk perception

| Model alternatives | Validation parameters. Recommended values in brackets, (24) | | | | |
|---|--|-----------------|----------------------------|--------------------------------|----------------------------------|
| | C_{\min}^a | df ^b | C_{\min}/df^c (< 2) | CFI ^d (> 0.95) | RMSEA ^e (< 0.10) |
| 1  | 23.751 | 12 | 1.979 | 0.955 | 0.107 |
| 2  | 61.832 | 13 | 4.756 | 0.815 | 0.209 |
| 3  | 30.997 | 13 | 2.384 | 0.932 | 0.127 |
| 4  | 23.909 | 13 | 1.839 | 0.959 | 0.099 |

295 ^a The C_{\min} value assesses the discrepancy between the model and a perfect fitting model.

296 ^b Degrees of freedom in the model

297 ^c The relationship between C_{\min} and the degree of freedom. By calculating C_{\min} ratio versus the
 298 degrees of freedom, the validity of the model fit can be normalised and assessed (30).

299 ^d The Comparative fit index (CFI), assesses the closeness to a perfect model (31).

300 ^e The Root mean square error (RMSEA) estimates the lack of fit compared to the perfect model (32).

301 Structural relationship models (model 2-4) were compared to a “test” model (model 1) in which no
302 structural relationship between parameters was assumed to exist, see Table 4. A presentation of the
303 comprehensive results is found in SI page S27- S31.

304 The different models are assessed by using a number of evaluation parameters that are recommended
305 in psychological research (33). As evident from table, model 4, which shows that risk perception is
306 dependent on controllability which is dependant on transparency, is the only model that fits better than a
307 model with no structural dependence between the parameters (model 1). This relation can only be
308 identified through structural equation modelling and may be important to notice in future stakeholder
309 involvement processes.

310 Correlations with preferences in disposal alternatives

311 A variance analysis was performed to investigate whether risk perception and related PAFs had
312 affected the preferences for the disposal solution (CAD/land) and therefore also had affected the
313 potential outcome of the decision making process. By using the F-test, systematic variation in the data
314 material exceeding random variation, was investigated. The results show significant differences relating
315 to *risk perception* ($F=56.3$; $df=1$; $\alpha<0.05$) and the structural related PAFs *controllability* ($F=27.2$;
316 $df=1$; $\alpha<0.05$) and *transparency* ($F=26.8$; $df=1$; $\alpha<0.05$) for the alternative solutions. With respect to
317 stakeholders’ objectives for the choice of a solution, no differences were found relating to *workability*
318 ($F=0.18$; $df=1$; $\alpha=0.67$). For the *health and environmental objectives* the F-test showed a significant
319 difference between the groups ($F=5.7$; $df=1$; $\alpha=0.02$). However both groups evaluated this factor as
320 important (value of 2) or very important (value of 1) for their choice of disposal solution. This makes it
321 plausible to assume that differences between the groups in practice are minor. See also SI Table S25 for
322 more information.

323 These findings supports the view that perceived risk and underlying PAFs are indeed vital for choice
324 of preferred remedial solution and therefore may be an important factor to address when selecting
325 disposal solutions in contaminated sediment management. This view is also consistent with the results
326 of the interviews where respondents preferring a land solution often expressed scepticism with regard to

327 the controllability of an aquatic disposal site, especially on a long term basis. The same respondents also
 328 often questioned the openness of the management process.

329 Socio-demographic and participatory aspects

330 In order to assess whether stakeholders' preferences for different disposal options were affected by
 331 socio-demographic and participatory aspects, a similar variance analysis was performed for these
 332 parameters, see Table 5.

333 Table 5 Variance analysis of socio-demographic and participatory aspects for the alternative
 334 solutions (CAD and land solution). F-test values and corresponding significance is given in the table.

| Subject | Item | Category | F | Sig. ^a |
|--------------------------|----------------------------|---|-------|-------------------|
| Socio-demographic aspect | Age | 1) 0-18, 2) 18,40, 3) 40-65, 4) > 65 | 1.48 | 0.29 |
| | Gender | 1) female, 2) male | 0.32 | 0.57 |
| | Education | 1) no formal, 2) primary school, 3) secondary school, 4) Bachelor, 5) Master, 6) Master ext., 7) PhD | 6.02 | <0.05 |
| | Work status | 1) unemployed, 2) student, 3) retired, 4) government empl. 5) company empl. 6) NGO, 7) freelance | 0.15 | 0.70 |
| | Residence | 1) at site, 2) Vicinity 3) Oslo, 4) outside Oslo | 1.54 | 0.22 |
| Participatory aspect | Year involved | 1) 1993-2004, 2) 2004, 3) 2005, 4) 2006, 5) 2007- | 0.28 | 0.60 |
| | Reason for involvement | 1) Listener, 2) knowledge supplier, 3) critical observer, 4) participant | <0.01 | 0.98 |
| | Cause | 1) Job, 2) interest only, 3) NGO | 3.43 | 0.07 |
| | Function | 1) outside decision process (private, journalist, NGO) 2) within the decision process (governmental, politician, consultant / researcher) | 13.95 | <0.05 |
| | Primary information source | 1) Project web NGO webs 2) Scientific reports 3) Meetings 4) Communication with project 5) Personal expertise 6) Project web 7) NGO webs | 0.12 | 0.73 |

335 ^a Bold face values indicate parameters where the F-test give a $\beta \neq 0$ (95% confidence)

336 For the socio-demographic aspects the only systematic variance was found for education, where
337 respondents with extended Master or higher degrees were more in favour of the selected solution, CAD
338 (see also SI table S26). It is interesting to see that geographical location, which tend to disfavour
339 disposal solutions close to residential areas (NIMBY-effects) (34) was not a significant distinguishing
340 element in choice of preferred disposal solution in this case.

341 Limited variance was also seen for the participatory aspects. The only systematic variance that was
342 identified, related to the stakeholders function in the project, where persons assumed to be closer to the
343 decision making process such as politicians, governmental organizations and consultants / researchers
344 were more in favour of the chosen solution (CAD), than persons assumed to be outside the decision
345 making process such as private persons, journalists and NGOs. The findings are consistent with the
346 results from the interviews, which indicated that people closely involved in the project were more in
347 favour of the selected solution than respondents with more peripheral connections to the project
348 organisation. Interestingly, among the interview respondents that were critical to the chosen solution
349 were some experts. However these experts were generally peripheral to the decision making process.
350 This critical attitude among the peripheral experts may be a sign of risk aversion (35), but is not
351 contradictive to the identified PAF of transparency of decision making and controllability as influencing
352 the preferential choice of disposal solution.

353 The results of this study are not consistent with the view that there is a sharp distinction in the risk
354 perception of experts (who traditionally make risk estimates) and other stakeholders (who are primarily
355 following individual interests independent from expert opinion). The results also support the view that
356 stakeholders can be very well informed and thus may form alternative expert opinions based on various
357 information sources (36). This finding is consistent with other studies which emphasize familiarity,
358 attitude and trust (and distrust) as important factors affecting risk perception, rather than demographic
359 aspects (37).

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362 Implications for future remediation decision making

363 A majority of the attention of the Oslo harbour remediation project has been directed towards the
364 selected aquatic disposal solution for contaminated sediments. The management decision or the decision
365 making process itself with regard to the disposal solution may therefore be considered as the catalyst for
366 the resulting social uneasiness. The stakeholders' preferences for disposal solutions were with the
367 exception of *education* and *risk aversion* not impacted by socio-demographical and participatory
368 aspects. This study therefore strongly indicates that management processes in projects concerning
369 contaminated sediments need to address the societal context and the broader interpretation of risk,
370 particularly questions related to the PAFs *controllability* and *transparency*.

371 In linking stakeholder values and knowledge (16), the sediment remediation project in Oslo harbour
372 may be characterized as a moderately structured problem with a high degree of convergence in values, in
373 this case expressed by remediation objectives, but a low convergence in perceived knowledge, in this
374 case represented by the perception of the risk involved. Thus, increasing the transparency of the decision
375 making process, particularly on items related to controllability, is recommended to account for in policy.
376 To address this kind of situation, Hirschmüller (16) recommends a stakeholder involvement process
377 using science-based negotiated policy. This management strategy involves the use of knowledge
378 accepted by the actors who have an interest in the issue (38). This strategy is also advocated in the
379 framework of the International Risk Governance Council (IRGC) (12,39) for ambiguous issues with
380 conflicting risk perceptive views. Several strategies have been previously described for stakeholder
381 involvement in contaminated sediment management that, like this one, recommend participatory
382 processes aided by decision analysis techniques such as multi criteria decision analysis (40-42).

383 This case study supports the view that there is no sharp distinction in risk perception between experts
384 and other parties involved. Non-expert stakeholders may be very well informed, adopt their alternative
385 expert opinion based on the various information sources available. As this study confirms, further
386 research on methods that allow for more open and transparent stakeholder involvement processes are
387 warranted, to assist in future management decisions.

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393 SUPPORTING INFORMATION

394 In this paper statistical analysis and modelling methods have been used to address the quantitative
395 data, and qualitative results have been used for triangulation. More information on the analyses and
396 background information are found in the supporting information for this paper. This information is
397 available free of charge via the Internet at <http://pubs.acs.org>.

398 REFERENCES

- 399 1. Lucas Simons; Adriaan Slob; Houke Holswilder; Arnold Tukker. The Fourth Generation: New
400 Strategies Call for New Eco-Indicators. *Environmental Quality Management*. **2001**, *11* (2), 51-61.
- 401 2. Remmen, A. Greening of Danish Industry - Changes in Concepts and Policies. *Technology*
402 *Analysis & Strategic Management*. **2001**, *13* (1), 53-69.
- 403 3. Keijzers, G. The evolution of Dutch environmental policy: the changing ecological arena from
404 1970-2000 and beyond. *Journal of Cleaner Production*. **2000**, *8*, 179-200.
- 405 4. Apitz, S. E. Is risk-based, sustainable sediment management consistent with European policy?
406 *Journal of Soils and Sediments*. **2008**, *8* (6), 461-466.
- 407 5. Bakke, T.; Kallqvist, T.; Ruus, A.; Breedveld, G. D.; Hylland, K. Development of sediment
408 quality criteria in Norway. *Journal of Soils and Sediments*. **2010**, *10* (2), 172-178.
- 409 6. Sparrevik, M and Breedveld, G. D. From Ecological Risk Assessments to Risk Governance.
410 Evaluation of the Norwegian Management System for Contaminated Sediments. *Integrated*
411 *Environmental Assessment and Management*. **2009**.
- 412 7. Slovic, P. Perception of Risk. *Science*. **1987**, *236* (4799), 280-285.
- 413 8. Starr, C. Social Benefit versus Technological Risk. *Science*. **1969**, *165* (3899), 1232-1238.

- 414 9. Slovic, P.; Finucane, M. L.; Peters, E.; MacGregor, D. G. Risk as analysis and risk as feelings:
415 Some thoughts about affect, reason, risk, and rationality. *Risk Analysis*. **2004**, *24* (2), 311-322.
- 416 10. Cross, F. B. Facts and values in risk assessment. *Reliability Engineering & System Safety*. **1998**,
417 *59* (1), 27-40.
- 418 11. Liberatore, A.; Funtowicz, S. Democratising expertise, expertising democracy: what does this
419 mean, and why bother? *Science and Public Policy*. **2003**, *30*, 146-150.
- 420 12. Renn, O. *Risk Governance. Coping with uncertainty in a complex world*; Earthscan, 2008.
- 421 13. Asselt, M. B. A. *Perspectives on uncertainty and risk, the PRIMA approach to decision support*;
422 Kluwer Academic Publishers: Boston, 2000.
- 423 14. Sjöberg, L. Rational risk perception: Utopia or dystopia? *Journal of Risk Research*. **2006**, *9* (6),
424 683-696.
- 425 15. Oen, A. M. P.; Sparrevik, M.; Barton, D. N.; Nagothu, U. S.; Ellen, G. J.; Breedveld, G. D.;
426 Skei, J.; Slob, A. Sediment and society: an approach for assessing management of contaminated
427 sediments and stakeholder involvement in Norway. *Journal of Soils and Sediments*. **2010**, *10* (2),
428 202-208.
- 429 16. Hisschemöller, M. Participation as Knowledge Production and the Limits of Democracy. In
430 *Democratization of Expertise?*; Springer: Netherlands, 2005.
- 431 17. Frewer, L. J.; Miles, S.; Marsh, R. The media and genetically modified foods: Evidence in
432 support of social amplification of risk. *Risk Analysis*. **2002**, *22* (4), 701-711.
- 434 18. Susskind, L.; McKernan, S.; Thomas-Larmer, J. *The consensus building handbook a*
435 *comprehensive guide to reaching agreement*; Sage Publications; Thousand Oaks, Calif, 1999.
- 436 19. Yin, R. K. *Case study research design and methods*; Sage Publications: Los Angeles, Calif,
437 2009.
- 438 20. Creswell, J. W.; Plano Clark, V. L. *Designing and conducting mixed methods research*; Sage
439 Publications: Thousand Oaks, Calif, 2007.
- 440 21. Sjöberg, L. The Methodology of Risk Perception Research. *Quality and Quantity*. **2000**, *34* (4),
441 407-418.
- 442 22. Plattner, T. Modelling public risk evaluation of natural hazards: a conceptual approach. *Natural*
443 *Hazards and Earth System Sciences*. **2005**, *5* (3), 357-366.
- 444
445

- 446 23. *SPSS Statistics Base 17.0 User's Guide*; SPSS Inc, 2009.
- 447 24. Tabachnick, B. G.; Fidell, L. S. *Using multivariate statistics*; Pearson/Allyn & Bacon: Boston,
448 2007.
- 449 25. *Amos 7.0 User's guide*; Amos Development Corporation, 2005.
- 450 26. Toma, L.; Mathijs, E. Environmental risk perception, environmental concern and propensity to
451 participate in organic farming programmes. *Journal of Environmental Management*. **2007**, 83 (2),
452 145-157.
- 453 27. Schafer, J. L.; Graham, J. W. Missing data: Our view of the state of the art. *Psychological*
454 *Methods*. **2002**, 7 (2), 147-177.
- 455 28. Cronbach, L. Coefficient alpha and the internal structure of tests. *Psychometrika*. **1951**, 16 (3),
456 297-334.
- 457 29. Nunnally, J. C. *Psychometric theory, 3rd ed*; McGraw-hill inc, 1994.
- 458 30. Browne, M. W. Asymptotically Distribution-Free Methods for the Analysis of Covariance-
459 Structures. *British Journal of Mathematical & Statistical Psychology*. **1984**, 37 (MAY), 62-83.
- 460 31. Bentler, P. M. Comparative Fit Indexes in Structural Models. *Psychological Bulletin*. **1990**, 107
461 (2), 238-246.
- 462 32. Browne, M. W.; Cudeck, R. Alternative Ways of Assessing Model Fit. *Sociological Methods &*
463 *Research*. **1992**, 21 (2), 230-258.
- 464 33. McDonald, R. P.; Ho, M. H. R. Principles and practice in reporting structural equation analyses.
465 *Psychological Methods*. **2002**, 7 (1), 64-82.
- 466 34. Dear, M. Understanding and Overcoming the Nimby Syndrome. *Journal of the American*
467 *Planning Association*. **1992**, 58 (3), 288-300.
- 468 35. Dyer, J. S.; Sarin, R. K. Relative Risk-Aversion. *Management Science*. **1982**, 28 (8), 875-886.
- 469 36. Sjoberg L and Drottz-Sjoberg B.M. Attitudes towards nuclear waste and siting policy: experts
470 and the public. In *Nuclear Waste Research: Siting, Technology and Treatment*; Arnold P.Lattefer
471 Ed.: Nova Science Publishers, Inc, 2008.
472

- 473 37. Poortinga, W.; Pidgeon, N. F. Trust, the asymmetry principle, and the role of prior beliefs. *Risk*
474 *Analysis*. **2004**, 24 (6), 1475-1486.
- 475 38. Bruijn, J. A.; Heuvelhof, E. F. Scientific expertise in complex decision-making processes.
476 *Science and Public Policy*. **1999**, 26, 179-184.
- 477 39. IRGC *An introduction to the IRGC risk governance framework*; IRGC: Geneva, Switzerland,
478 2007.
- 479
- 480 40. Yatsalo, B. I.; Kiker, G. A.; Kim, J.; Bridges, T. S.; Seager, T. P.; Gardner, K.; Satterstrom, F.
481 K.; Linkov, I. Application of Multicriteria Decision Analysis Tools to Two Contaminated
482 Sediment Case Studies. *Integrated Environmental Assessment and Management*. **2007**, 3 (2), 223-
483 233.
- 484 41. Menzie, C. A.; Booth, P.; Law, S. A.; Stackelberg, K. *Use of Decision Support Systems to*
485 *Address Contaminated Coastal Sediments: Experience in the United States*; Springer: US, 2009.
- 486 42. Linkov, I.; Satterstrom, F. K.; Kiker, G.; Batchelor, C.; Bridges, T.; Ferguson, E. From
487 comparative risk assessment to multi-criteria decision analysis and adaptive management: Recent
488 developments and applications. *Environment International*. **2006**, 32 (8), 1072-1093.
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496 TABLE OF CONTENTS BRIEF

497 A broader representation of risk and risk perceptive affective factors (PAF) are important to address in

498 stakeholder involvement processes regarding contaminated sediment disposal

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