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

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ABSTRACT

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

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

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

Introduction

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

Policy development for the management of contaminated sediments has lagged behind development in other areas. Part of this is related to the ambiguous nature of regulating polluted sediments. Many sites are contaminated from previous activities ("old sins") and by diverse pollution sources, making it unclear who bears the burden of blame or remediation. Contaminated sediments are therefore still generally managed through a strong post-pollution regulative focus similar to the early stages of environmental policy (*4*), rather than through a preventative focus. In Norway and some other countries, however, the awareness of preventive measures has grown, and precautionary ecological risk assessments, which are used to identify, characterize and quantify environmental hazards, has been advocated (*5*).

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

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

The gap in risk perception between different parties in the management process may, according to empirical research, only be bridged through communication and involvement, and by placing the same emphasis on lay perception as is placed on technical knowledge (*13*). On the other hand, diversity in risk perception may also be an asset since it avoids concealing important hazards. Examples of such behaviour was found in the Former Soviet Union were unwanted hazards were regularly concealed (*14*). Complete consensus may therefore be both unrealistic and in many cases unwanted.

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

Materials and Methods

Study object

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

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

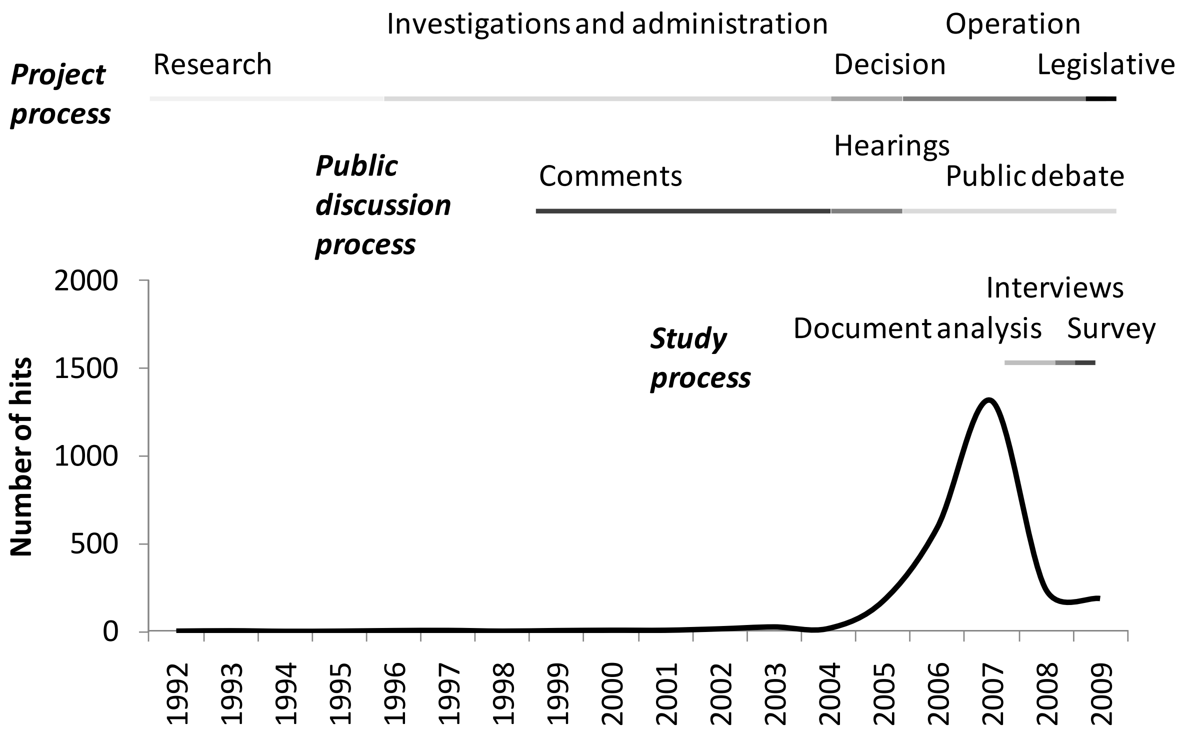


Figure 1 Overview of the project and related public discussion process as measured by number of materials published in Norwegian published media (television, radio, the Web and newspapers) found in the Retriever® database (www.retriever-info-com) using the search word "Malmøykalven"

The project process started with "research" period that assessed the potential consequences of contaminated sediments to people and environment. This period was followed by a sediment "investigation and administration" period to map the present situation and to come up with potential remedial solutions. Assessing the feasibility of using the CAD at Malmøykalven was an important activity during this phase. Both the use of the CAD and transport to the site with barges were subjected to an environmental impact assessment (EIA). The proposed solution was evaluated against a no-remediation scenario and was found to be feasible. Alternative disposal solutions were only briefly discussed in the EIA. After several political delays, the need to find a solution became urgent in 2004 due to urban development in the harbour area and the construction of a submerged road tunnel. During the brief "decision" phase a development plan was produced and a formal decision process was initiated. This process was finalized in 2005 and resulted in the decision to start the dredging activities immediately and to use the CAD as a disposal solution. The operation started early in 2006 and continued until mid 2009 during the “operation” phase.

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

Data collection

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

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

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

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

To confirm and support the main conclusions from the interviews an anonymous web survey with closed questions relating to the above mentioned topics was conducted during the winter 2009. Questions are presented in SI pages S9-S14. Recruitment to the survey was based on the original stakeholder list of 160 people, omitting interviewed key stakeholders and people without valid e-mail addresses. This resulted in a list of 92 names. In addition, interviewed key stakeholders were submitted an e-mail with the link to the survey with a request to forward the survey to persons they considered suitable. The survey included questions that were tailored to identify and exclude responses not relevant to the proposed stakeholder population definition. The survey received 87 valid responses within a time period of 44 days, whereof 49% were directly recruited parties and 51% were forwarded answers. The response rate among the recruited was 50%. The answers consisted of 29% female and 71% male responses. The majority of the respondents (55%) were between 41-65 years old. Sixty-five percent of the respondents lived in Oslo, but people living in the vicinity of the disposal site were also represented, (23%). The vast majority of the respondents (94%) had university education (Bachelor, Master or PhD).

Identification of risk perceptive factors and their relationship

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

Table 1 Overview of generic and project specific affecting factors (PAF) influencing perceptions of risk[1].

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

1 Adapted from (*22*)

The four main PAFs summarised in Table 1 are voluntariness, knowledge, endangerment and reducibility. *Voluntariness* relates to the risk attitude of people and the willingness to take risks. *Knowledge* incorporates a broad spectrum of items relating to information, general confidence, involvement and transparency as well as formulations of objectives. *Endangerment* incorporates the question on how the risk may affect humans and the environment, either negatively or positively. Finally, the *reducibility* relates to possible negative considerations associated with use.

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

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

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

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

The second part of the statistical work investigated the correlation between the identified PAF and the perceived risk related to the CAD. The question about perceived risk had been included in the survey as a separate model question. This investigation of correlation was performed using a linear regression model with risk perception as the dependent variable (DV) and the identified PAFs as independent variables (IV). Only IV's with significant correlation to perceived risk of the CAD were retained for subsequent analysis.

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

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

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

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

Results and Discussion

Determining perceptive affecting factors

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

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

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

Model question	N [a]	Factor analysis results for the project specific perceptive affecting factors (PAF)[c]			
		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	-.016	**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	-.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

[a] Number of respondents before missing value replacement

[b] Cronbach alpha reliability value. A value above 0.70 is normally considered to be acceptable (*29*).

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

The first PAF *controllability* incorporates perceived effect, spreading of contaminants, potential change in future consumption patterns and perception of sediment risk after project execution. This PAF incorporates both endangerment and reducibility, which were not possible to distinguish between in the analysis. The second and third PAF, *workability* and *health-environmental objectives*, respectively, relate to stakeholders' objectives when selecting the preferred disposal solution. The analysis clearly distinguishes between reduction in human and environmental risk by using the preferred solution and objectives related to the workability of the solution, such as the importance of handling contaminated sediments locally and the importance of an added value other than reduction of environmental risk. The fourth PAF *transparency*, also relates to knowledge, and specifically to transparency in the decision making process with emphasis on accessibility and sufficient time to involve stakeholders in the decision.

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

Table 3 Arguments, relating to determined PAF, assessed as important by the interviewed key 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

A majority of the interview respondents felt that aquatic disposal had a different risk than other solutions and mentioned different arguments related to controllability, including chemical stability, spreading of contaminants during disposal, weather and stream conditions as well as long term effects as important in risk assessment.

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

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

PAFs vs. risk perception

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

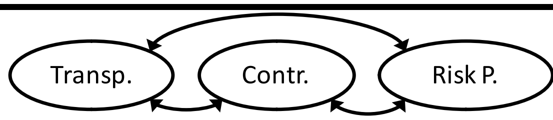
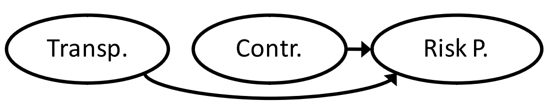
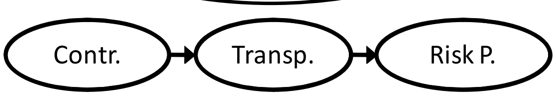
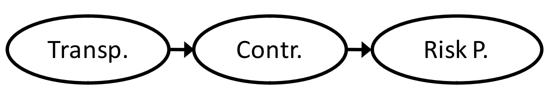
Sensitivity analysis

One important item in the PAF factor analysis is outcome sensitivity with respect to the model questions selected. The study represents a substantial sample of the population, which is satisfactory. On the other hand the sample material is limited and has been subjected to a missing value analysis, which may reduce the statistical reliability. A sensitivity analysis performed using a modified approach that included additional factors that had initially been discarded did not identify additional dependent variables compared to the initial solution (see SI Table S12). The results from this modified approach showed that *controllability* was still correlated to perceived risk when more model questions were included, whereas *transparency* was no longer correlated (SI Table S14). In an ideal situation the web survey should have been altered and repeated for the ambiguous model questions. However, due to the sensitivity of the project, the web survey was performed anonymously and was conducted in an on-going project process and could therefore not be repeated. Since the results from the interviews confirmed the survey results the initial approach was retained.

<u>Structural relationship</u>

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

Table 4 Statistical analysis (SEM) of the structural relationship between the PAFs transparency 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

[a] The C_{min} value assesses the discrepancy between the model and a perfect fitting model.

[b] Degrees of freedom in the model

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

[d] The Comparative fit index (CFI), assesses the closeness to a perfect model (*31*).

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

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

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

Correlations with preferences in disposal alternatives

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

These findings supports the view that perceived risk and underlying PAFs are indeed vital for choice of preferred remedial solution and therefore may be an important factor to address when selecting disposal solutions in contaminated sediment management. This view is also consistent with the results of the interviews where respondents preferring a land solution often expressed scepticism with regard to the controllability of an aquatic disposal site, especially on a long term basis. The same respondents also often questioned the openness of the management process.

Socio-demographic and participatory aspects

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

Table 5 Variance analysis of socio-demographic and participatory aspects for the alternative 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

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

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

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

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

Implications for future remediation decision making

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

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

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

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SUPPORTING INFORMATION

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

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TABLE OF CONTENTS BRIEF

A broader representation of risk and risk perceptive affective factors (PAF) are important to address in stakeholder involvement processes regarding contaminated sediment disposal