Environmental Assessment
Hot Mud Flow
East Java, Indonesia

Consolidated report on activities Undertaken through the Joint UNEP/OCHA Environment Unit

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Executive Summary

Overview

Since 29 May 2006, a mud volcano has been emitting hot mud in the Sidoarjo district of East Java, Indonesia. Mud volcanoes are geological phenomena due to over-pressurized, subsurface mud layers. The cause of the eruption has not yet been established. However, it may be linked to the gas exploration activities by Lapindo Brantas at the Panjar Banji I well.

The mud volcano in the Sidoarjo district emits mud at an average rate of more than 40,000 m^3/day, and has inundated 4 adjacent villages, displacing nearly 7,000 people. Almost 12,000 medical treatments have been carried out, mainly for people affected by the release of hydrogen sulphide gas.

On 20 June 2006, the Indonesian Ministry of Environment (KLH) requested technical assistance with the identification of environmental impacts of the mud flow from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA). The OCHA Environmental Emergencies Section, in collaboration with the OCHA Field Coordination Support Section, deployed a United Nations Disaster Assessment and Coordination (UNDAC) team with five environmental experts from 25 June to 6 July 2006. The team was supported by the Policy Support Team for Environmental Incidents (Bot-Mi) of the Netherlands. Following a second request made by the Indonesian Ministry of Environment at the end of the UNDAC emergency mission on 27 July 2006, an environmental expert was redeployed to Indonesia. The government of Switzerland kindly provided the expert for this follow up mission.

This report contains the technical findings, conclusions and recommendations, including results of analysis by the Institute for Public Health and the Environment in the Netherlands from the first mission, as well as the report of the follow-up mission. The latter is provided in Annex IV.

Summary of findings, conclusions and recommendations

Findings and conclusions

The following is a brief summary of the findings and conclusions. More detail on each of these findings and conclusions can be found in section 3 of this report.

- The current impact on human health and the environment is low due to containment of the mud in above ground basins.
- The above-ground basins are not a sustainable solution.
- Sudden release of the mud into an aquatic environment will kill the aquatic ecosystem and have serious humanitarian consequences.
- Normal levels of organic compounds (including phenols) have been found in the mud.
- Air samples and measured air quality do not show concentrations of toxic gasses (including hydrogen sulphide) above expected levels.
- Risks from recurrent toxic gas emissions, earthquakes and subsidence are unknown, but should be considered.

- More research and monitoring of the quality of the mud are needed before final statements can be made on the toxicity of the mud. However, organic compounds, and heavy metals including phenol and mercury are not found to be above normal levels.

Recommendations

The following is a brief summary of the recommendations. More detail on each of these recommendations can be found in section 3 of this report.

- Reinforcement of the above-ground basins is urgently needed.
- The local environmental authorities should strengthen their coordination, analysis and interpretation capacity focusing on heavy metals (in particular mercury) and salinity/conductivity (as an indicator for the dispersion of the mud).
- Development of a medium term strategy based on a number of options, including a worst case scenario is urgently required.
- The UN agencies currently involved should continue to monitor the humanitarian impact on the affected population.

The continuous mudflow has submerged various villages. Photo: R. Nijenhuis

1 Introduction

Situation

On 29 May 2006, two days after the earthquake that struck Yogyakarta, Indonesia and killed almost 6,000 people, a mudflow stemming from or near the Banjar Panji I gas drilling well in Sidoarjo district in the East Java Province was reported. The mud was estimated to be flowing at a rate of 5,000m^3/day and rapidly flooded surrounding areas, displacing thousands of people. In addition, between 800 and 900 people had to seek medical treatment after exposure to, and inhalation of a poisonous gas.

On 20 June 2006, OCHA received a request for technical assistance from the Indonesian Ministry of Environment. In coordination with the United Nations Resident Coordinator (a.i.), it was decided to deploy an UNDAC team with environmental experts.

International collaboration

The governments of the Netherlands and Switzerland kindly provided UNDAC with trained environmental experts for this mission. In addition, the Netherlands Government made available two associate experts of the Dutch National Institute of Public Health and the Environment (RIVM) for sampling and analysis. OCHA's Environmental Emergencies Section (EES) provided a team leader for the mission.

Together with the Indonesian Ministry of Environment, it was agreed that the team would provide technical assistance to the environmental authorities with the identification of environmental impacts of the mud, and based on the outcomes, provide recommendations for mitigation. In particular, independent sampling and analysis would be undertaken -in the field and Jakarta- with a primary aim to establish indications to determine the 'toxicity' of the mud. This criterion is the most important parameter to determine environmental impact of the mud and will also determine options for the management of the mud (i.e., should the mud be classified as toxic waste or as a resource for agricultural purposes).

This report

This technical report provides an overview of the findings, conclusions and recommendations of the team at the end of their field mission, supported by analysis undertaken at RIVM in the Netherlands. Extensive scientific support has been received from various research institutions in the Netherlands, in particular from the Policy Support Team for Environmental Incidents (BOT-Mi).

Using the same methodology as in the report, indications for a future outlook – including possible options for the management of the mud have been provided in section 4 of this report.

2 Findings and Observations

This section provides an overview of the findings and observations obtained during the field visits, sampling and analysis, and review of existing data and interviews with important actors in East Java Province.

Banjar Panji I well

The Banjar Panji I is an exploration well that was commissioned to determine the feasibility of exploiting an underlying rich natural gas formation (named the ”Kunjung formation”). The well had reached a depth of over 3,000 metres when three different mud flows started. The first and largest flow started on 29 May 2006 and is situated at 200 metres south west of the drilling well. On 2 June 2006, a second mudflow appeared, while the next day, a third mud emission started. The second two mud flows were situated between 800 and 1000 metres north east of the gas drilling well and apparently both stopped flowing on 5 June 2006.

Mud volcanoes

Volume of mud

On 21 June 2006, Lapindo Brantas (the owner of the well) calculated the volume of mud emitted since 29 May 2006, based on surface and depth measurements using Global Positioning System. On that date, the volume was estimated to be 1.1 million m^3 of mud. The depth of the mud was ranging from 3.5 to 6.4 metres around the source of the mudflow, to 0.1 to 0.6 metres at the edges of the flood zones. Although the flow is not continuous and the mud volcano is intermittently active, the estimated average volume of emitted mud over that period would have been over 40,000 m^3/day. At the time of writing, the flow is continuing.

Possible cause

Based on interviews with Lapindo Brantas geologists, it appears that the mudflow stems from a geological phenomenon known as a mud volcano. Mud volcanoes are not uncommon and can occur both on the surface and at ocean bottoms worldwide. They are often associated with petroleum deposits.

Reportedly, the island of Java has experienced a number of mud volcanoes before, of which one has now been active for several years. This active mud volcano is situated approximately 200 km west of Sidoarjo district, near Purwodadi.

A possible explanation for the cause of the mud volcano eruption is that a pressurized mud layer, which also contained hydrogen sulphide (H_2S), was pierced by the gas drilling well or found its way ‘spontaneously’, vertically upwards to the surface.

A **mud volcano** is a small volcano-shaped cone of mud and clay, usually less than 1-2 m tall. These small mud volcanoes are built by a mixture of hot water and fine sediment (mud and clay) that either (1) pours gently from a vent in the ground like a fluid lava flow; or (2) is ejected into the air like a lava fountain by escaping volcanic gas and boiling water. The fine mud and clay typically originates from solid rock--volcanic gases and heat escaping from magma deep below turning groundwater into a hot acidic mixture that chemically changes the rock into mud- and clay-sized fragments.
Source: http://volcanoes.usgs.gov

Government investigations

Government investigations are ongoing to establish whether the drilling of the exploration well has caused the mud volcano to erupt and no speculations can be made until the findings of these investigations have been published.

Toxic gas: hydrogen sulphide

As noted above, the eruptions were associated with the release of a toxic gas, most likely to have been hydrogen sulphide (H_2S). Measurements reported by the Indonesian Ministry of Environment, stated that hydrogen sulphide levels reached 700 parts per million (ppm) on the first day (apparently at the source), while the concentration dropped to 3 ppm on the second day of the events, down to 0 ppm on the third day. Although no further information about these measurements is known, the concentration of 700 ppm would suggest a direct and acute impact on human health – and can be fatal.

Hydrogen sulphide is a colorless, toxic, flammable gas that is responsible for the foul odor of rotten eggs. It often results when bacteria break down organic matter in the absence of oxygen, such as in swamps, and sewers. It also occurs in volcanic gases, natural gas and some well waters. **Source: http://en.wikipedia.org/wiki/Hydrogen_sulfide**

It is assumed that the hydrogen sulphide was contained in the over pressurised mud layer. During the site visits and sample taking, detectors were used (to ensure on-site safety of the team) and no hydrogen sulphide was detected. In addition, large numbers of people on and near the mud volcano confirmed that no release of toxic gases was taking place.

Sophisticated equipment was used to measure air quality. Photo: F. Fortezza

Humanitarian and infrastructure impact

The mudflow has inundated the adjacent villages of Renokenongo, Siring, Jatirejo and Kedungbendo. As of 4 July 2006, the total number of displaced people was up to 6,915 (1,788 households). Local authorities have provided temporary shelter in the Pasar Baru Porong (a market due to be opened in July) for 5,664 people and in the Balai Desa Renokenongo for another 717 people. In addition, 534 people have been hosted by families in safer locations. There are 1,382 school-aged children among the total number of Internally Displaced People (IDP).

Four hospitals and 13 health posts have treated an accumulated number of 11,494 people, of which 215 were inpatients. On 4 July 2006, 34 people were still in local hospitals/health posts. Patients have been treated for acute respiratory tract infection and digestive problems, such as diarrhoea.

On 15 June 2006, the Indonesian Department of Health sent three metric tons of supplementary baby food and seven metric tons of fortified biscuits to Sidoarjo District. Food and non-food items (including instant noodles, coffee, sugar, mineral water, rice, milk, biscuits, cooking oil, soaps, and sleeping mats) have been provided by a range of entities, such as the House of Representatives, local government, local community organizations, private sector and Lapindo Brantas.

Affected infrastructure

Facilities (other than houses) inundated by the mud include 17 schools and 15 factories. Compensation will be provided to the affected population and labourers affected by the closure of the factories.

The types of small and medium sized factories inundated by the mud, include clock and watch production, steel construction, food production (drinks and crackers) and rattan furniture production. Hazardous materials used in these factories may have formed a secondary pollution into the mudflow.

The Surabaya-Gempol toll road has been closed as mud is flowing from the southern flood zone over a stretch of 50 metres into the northern flood zone (see the aerial overview on page 6 below). The local police have deployed around 250 personnel per day to guard the abandoned houses, provide security in the temporary shelters and direct traffic.

There have been tensions between communities on both sides of the toll road protection dam, particularly when mud levels started rising and threatened to flood villages. Reportedly villagers broke the dam, resulting in flooding on both sides.

Emergency response

As the mud volcano and mudflow has not been declared a national disaster, the overall coordination and responsibility for the emergency response rests with the provincial authorities, i.e., the Governor of East Java. Based on their assessments of the situation, the provincial authorities have established the following three main objectives:

- stem the flow
- manage the social impacts
- minimize the environmental impacts.

Stem the flow

The first objective is to stem the flow of mud from the source. A snubbing unit[1] will be used through the existing well to try to stop the mud flow. This is based on the assumption that the mud volcano was caused by piercing the subsurface over pressurised mud layer by the gas drilling well. It is expected that this effort will take approximately one month (until the end of July).

If this measure fails, a relief well can be drilled as a second subsurface action to stop the mudflow. Drilling a relief well can take up to three to four months and so far there are no indications that this will guarantee stoppage of the mudflow. The snubbing unit and relief well efforts will be carried out by Lapindo Brantas, BP Migas (Regulatory Body for Oil and Gas of Indonesia) and ESDM (Department of Energy and Natural Resources).

Manage the social impacts

The second objective of the authorities is to manage the social impacts associated with the mudflow. Local government authorities, including Satlak (the district implementation unit for disaster management) are trying to mitigate the social impacts by providing shelter and food for displaced people, arrange compensation payments for loss of work and income, and further sensitize the affected population to the response activities. No international organisations have been involved in the response activities of this disaster.

Minimize environmental impacts

The third objective is to minimize the environmental impacts by containment of the mud in above-ground basins or ‘ponds’. These efforts are led by the Indonesian Ministry of Environment, in cooperation with the Sepuluh November Institute of Technology of Surabaya (ITS), and the Army Corps of Engineers.

The above ground basins are constructed with two metre high earth walls, and are filled with the mud by both gravity and the use of pumps. The table below shows the planned basins including their surface and capacity. These basins should be finished and filled before the end of July. However, taking the average emission of 40,000 m^3/day experienced during the first three weeks, the first phase of basins will be filled within 26 days.

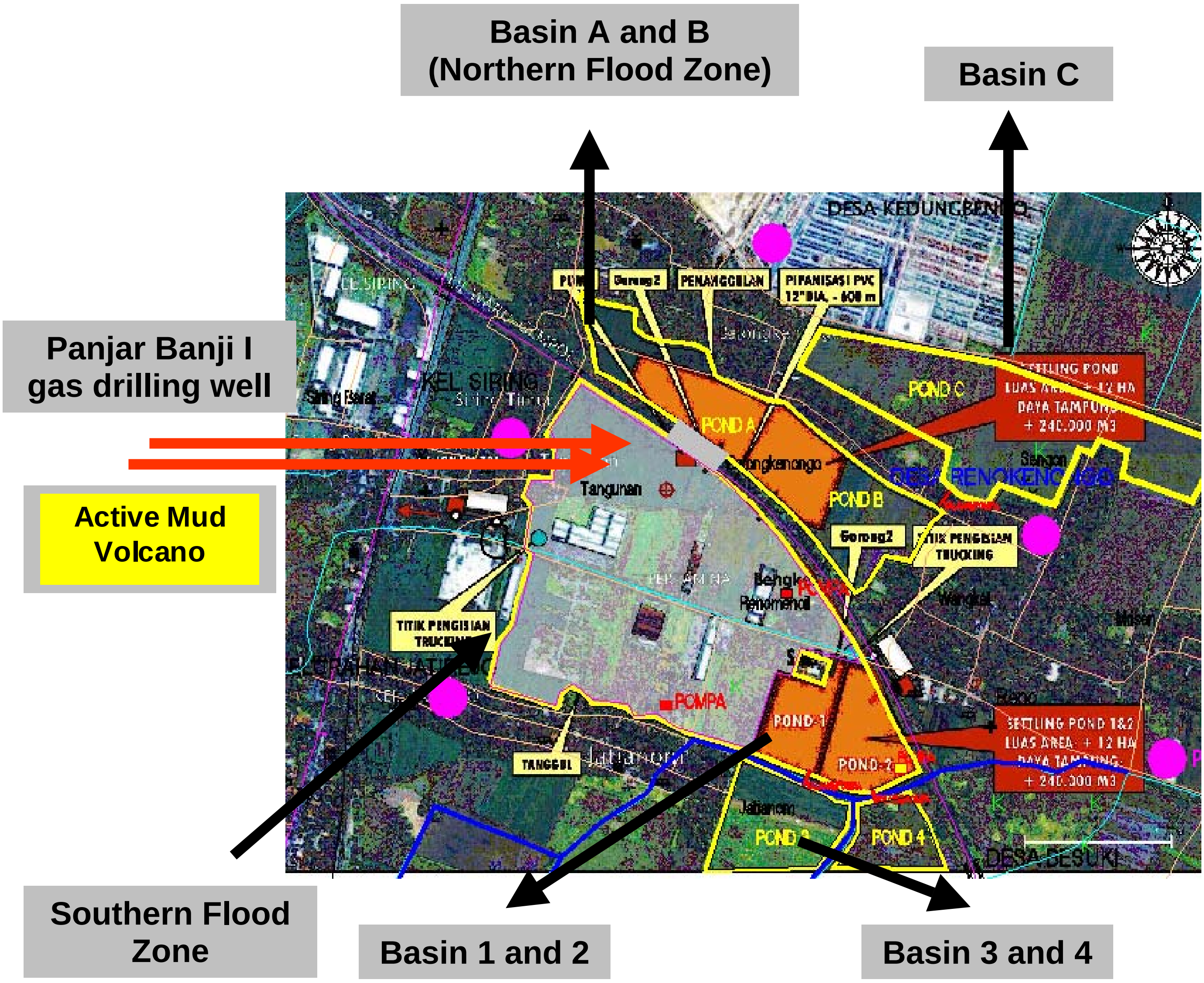
Above ground basin	**A**	**B**	**C**	**1**	**2**	**3**	**4**	**Total**
Surface (ha)	24		32	12		12		**80**
Volume (‘000 m^3)	360		320	180		180		**1040**

[1] Snubbing is the act of putting drill pipe into the wellbore when the blowout preventers (BOPs) are closed to contain the pressure in the well. (http://www.glossary.oilfield.slb.com/Display.cfm?Term=snubbing).

As a second phase, the construction of a 145-ha basin is anticipated for September 2006. An even larger pond is planned to provide storage capacity for up to two years.

Overview of the affected site

The image below provides an overview of the active mud volcano, various above-ground basins, and the affected villages superimposed on a satellite image taken in 2002. The shaded area shows the mud flood zones north and south of the Surabaya-Gembol toll road reflecting the situation around 20 June 2006.



The village of Renokenongo is situated only a few hundred metres south of the mud volcano and is entirely inundated by 2 metres of mud. The village of Siring is situated in the northwest corner of the Northern Flood Zone. The village of Jatirejo is on the bottom left corner of the image (to the right of the railway track).

Environmental assessment

The overall objective of the environmental assessment of the current situation is to provide an indication of the hazards to the population and the impact on the environment. The impact of the current situation can best be estimated by reviewing the possible hazard (defined by the characteristics and toxicity of substances present), the quantity, and the exposure of the main receptors as shown in the equation below:

IMPACT = QUANTITY x HAZARD x EXPOSURE

The main receptors for which the hazard, quantity and exposure need to be evaluated are the:

- population that is potentially exposed to the mud and air originating from the mud volcano, and
- local environment (e.g. paddy fields, fish ponds, rivers and the marine environment).

Review of existing sampling and data analysis

Different institutions (government and universities) are currently involved in analysing samples taken from the mud. Unfortunately, because there was no agreed methodology, objective, nor analytical procedures, it is impossible to accurately compare the existing data.

UNDAC team review

The UNDAC team organized a meeting with the organisations involved in monitoring (sampling, measurement and analysis) as part of their environmental impact assessment. The meeting was attended by Bapedalda, ITS and two other laboratories, as well as the Deputy-Minister of Environment. An overview of the sampling, measurement, analysis and conclusions were presented and shared.

From the presentations made, the sampling strategy seemed to be good given the limited capacity and the amount of analysis. The basic analytical methods used to identify inorganic compounds were considered in principle, valid. Due to the time restrictions of the mission no detailed evaluation of the total procedures of sample handling and preparation could be carried out.

It was found during the review that analytical procedures applied by the individual institutions were not always valid, or adapted to the specific requirements of the emergency – in particular, irrelevant parameters and incorrect procedures were observed. Not all details of the sample methodology, procedures and data were accessible. Accredited laboratories (such as the forensic laboratory) could, however, be used to improve the credibility of the data.

The overall impression is, however, that the capacity and facilities available are sufficient to undertake the required sampling and monitoring of the situation.

Review of analysis approach

Organic compounds were analyzed by a method that is not valid or distinctive enough to identify the individual compounds. Phenol is reported to be present but the methods applied would not allow its detection.

Due to the lack of an agreed analytical procedure tailored to the emergency, samples were analysed using routine sets of parameters and analyses that do not necessarily apply to the current situation. For instance, water quality parameters such as Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are not relevant for the analysis of mud as mud does not contain organic matter. These irrelevant parameters contributed to the confusion in interpreting the samples.

To obtain an overall analysis of the mud, water should not be separated from the solid phase. In addition, the results were compared with ambient quality standards that apply to the discharge of water to the surface water. No dry weight content of the samples was determined. However, soil quality standards might need to be applied depending of the use or disposal of the mud at a later stage. For a comparison with soil quality standards, the concentrations of the components in the solid phase require analysis of the dry weight content.

Air quality was analyzed and monitored for a number of specific components, however not for Volatile Organic Compounds (VOC), which could be expected to be present in the mud and vapour from the volcano at the high temperatures.

Summary of data and analyses

Listed below is a summary of the data and analyses conducted by the different institutions to date:

- All concentrations of metal and mercury are low and below the standards in the samples shown. Discussion, however, made clear that some samples showed high concentrations of metal. The mud seems to not be homogenous. A secondary source of pollution (possibly from the industrial facilities) might explain these concentrations.
- Air concentrations of SO_2, H_2S, CO, NO_2 are low (most below detection limits).
- It is not clear if concentrations of H_2S where high during the incident and the press reported effects are linked to emissions.
- Apart from the overall monitoring group formed by KLH, the forensic laboratory, agricultural university of Bogor (West Java), and Public Works authorities where also investigating the quality of the mud. No formal interaction between these groups was noted. The facilities of the forensic laboratory are expected to meet the quality standards needed (accredited laboratory including quality control and cross referencing).
- The release of analytical results and consolidation of the results did not meet with the pace of the emergency and the required decision making process.
- Difficulties are noted with the interpretation of the available information and dealing with uncertainties.
- The analyses carried out were resource driven (normal measurements and routines) without a focus on the parameters critical for the specific incident and crisis management.
- No timeframes, sequence nor deadliness for the delivery of consolidated factual information where set.

Independent sampling and analysis by the UNDAC team

In addition to the review of the data and analyses by the local institutions, the UNDAC team conducted independent sampling and analyses. The objective was to provide a reference and verification of a complete investigation (information gathering, sampling, analysis and interpretation) to the environmental authorities to identify toxic substances and subsequent hazards to the population and environment.

Identification of organic and inorganic compounds

In order to provide the most added value to the existing data, priority was given to the identification of organic and inorganic compounds present in the mud and air (sampling and analysis) of the emission point and at locations where the population is exposed. A detailed description of the research strategy, methodology and results are provided in Annex (I).

Additional activities

The following additional activities were also carried out:

- Supervision of organic compound analyses in the mud samples taken by KLH.
- Joint identification and interpretation of the results of samples with high heavy metal contents together with ITS according to the Dutch water-, sludge- and soil standards. **Note:** The Dutch water quality standards add to the currently used Indonesian standards of “discharge water into surface waters”. No sludge or soil standards were available. The intended use, discharge or disposal of the mud determines what standards should be applied (water, sludge or soil).

Results

Upon return of the team, RIVM undertook a full scan and identification of organic and inorganic substances in the mud and air samples taken by the UNDAC team for cross referencing. In addition radiation levels of the mud were measured. The results are summarized in the table below:

Identification of	Results
Heavy metals in mud	All low, most of them like normal background values
Organic compounds in air (by active and passive samplers):	• Concentrations of benzene and toluene elevated at the source and the “exposure” location. • Xylenes and hydrocarbons are elevated. **Notes:** Based on the spectrum of this, different components and the fact that the “upwind” reference sample contains the same spectrum (although lower concentrations) we draw the conclusion that these components do not originate from the mud. Near to the sampling sites human activities take place (digging, pumping of mud, traffic) that allow concentrations of substances in this spectrum to occur. The upwind location was influenced less by these kind of activities.

Organic compounds in mud	No major elevations.
Radiation	Normal background values or even below detection limits for all types of radiation.

Analysis of the environmental assessment

Summary of methodology

The methodology used by the UNDAC team to assess the impact of the current situation and possible future developments took into account the:

- danger (characteristics and toxicity of substances present)
- quantity, and
- exposure of the main receptors.

Each element of the equation was assessed, and estimated to be either, LOW, MEDIUM or HIGH. The overall impact is deemed to be 'HIGH' only if the impact of all three elements is HIGH. All currently available data was taken into account including an expert judgment of the validity and representation.

Impact assessment

The indicative impact assessment is presented in the table below. It describes the individual assessment of the three components (mud, water and air) and the overall assessment of the environmental impact.

Comments on the assessment

The analysis of heavy metals in the current samples were expected to be valid, and no great variations were found with the analysis undertaken at RIVM.

The samples reviewed and analysed indicate a heterogeneous composition of the mud. It is not determined whether this is due to the geological composition of the mud or due to a source of secondary pollution. There is a variation in the concentrations of heavy metals between samples taken by KHL and ITS.

The impact on the environment is believed to be mainly the direct impact of the mud to the underlying soil. Due to the high water table in the area of the mud volcano, contamination of the ground water is believed to be limited. The impact on shallow wells cannot, however be confirmed.

Assessment matrix of the current situation

Component	Critical parameter	Impact	Quantity/Concentration	Hazard- to the receptor	Exposure of ecosystem	Exposure of humans
Mud	Heavy metals	LOW	MEDIUM AND HIGH Local elevation of heavy metals and especially mercury. The quality is not homogenous and concentrations vary by location.	HIGH High toxic solids and highly toxic solids (mercury).	LOW Limited and local, no vulnerable systems and good binding to the material/sludge	LOW Limited, because of lack of contact (direct and indirect via intake/consumption/food chain) and good binding of toxicant to sludge
Mud	Organic compounds, Including Phenols	LOW	LOW Elevated concentrations, at background concentrations. Special variation not known due to shortage of analysis. Expected to be homogeneous.	HIGH Toxic compounds	LOW Limited and localised no vulnerable eco-systems	LOW Not relevant due to small quantities and dilution in air.
Mud	Salinity	LOW	HIGH	LOW/ MEDIUM	LOW	LOW
Mud	Suspended solids	LOW	HIGH	LOW/ MEDIUM	LOW	LOW
Air	Volatile Organic Compounds	LOW	LOW Elevated concentrations, at background concentrations. The volatile compounds are expected to only be emitted directly from the source, not from the mud.**	HIGH Toxic, carcinogenic gasses.	LOW Limited and local, no vulnerable systems	LOW Not relevant due to small quantities (low concentration) and dilution in air*

Notes:
*Although the concentrations in the ambient air are low and no health effects are to be expected, the compounds have a low detection level for humans. In other words, the UNDAC team and the population note a “smell nuisance”.
**Due to high temperature of the mud (90 degree Celsius) the volatile substances are evaporating from the mud almost directly at the source.

3 Conclusions and Recommendations

Overview

The UNDAC mission based its results on the best available information at the time of writing. The emergency situation surrounding the mud volcano and the many actors working on the solutions may result in conclusions and recommendations losing their validity as more information becomes available or as the situation changes. The team has done its best to specify, where possible, the assumptions it had to make as well as the arguments for them.

It should be explicitly stated that due to the large volume of the mud being emitted and areas covered, the conclusions and recommendations in this report are indicative only.

Conclusions

Listed below is a brief summary of the concluding points. Each of these points is explained on the pages below:

- impact on human health and the environment
- sustainability of the above-ground basins
- impact of sudden release of the mud
- toxicity levels
- risks
- existing measuring and monitoring capacity.

Impact on human health and the environment

Samples and analysis indicate that the current impact of the physical and chemical characteristics of the mud on human health and environment is expected to be low, mainly due to the current practice of containment of the mud in above-ground basins. As an emergency response measure, the containment of the mud in above-ground basins is the best solution. Containment in basins limits exposure of the mud to humans and the environmental impact.

Sustainability of above-ground basins

The above-ground basins are considered unsustainable due to the following factors**:**

- dam wall collapse
- approaching rainy season (overflow, saturation)
- continuous emission of mud (average 40,000 m^3/day).

Dam wall collapse has been observed during the mission. The cause of dam wall collapse is unknown. The rainy season normally starts in October, with mean total rainfall increasing from 47 mm in October to 105 mm in November and 327mm in January. This will most likely lead to overflow of the above-ground basins and saturation of the dam walls, resulting in dam wall collapse. There is no guarantee that the mudflow can or will be stopped. In any case, the mud flow will continue for months, and in a worst-case scenario, for years and exacerbate the humanitarian situation.

Impact of sudden release of mud

The mud is characterised by high salinity (comparable to sea water) and high turbidity (sediments) and can create anaerobe conditions.

Sudden release of the mud into an aquatic environment (river, sea) will result in 'killing' the aquatic ecosystem with serious implications for those people dependent on these ecosystems (fish ponds, sea fishing). Release of mud onto agricultural land will destroy crops. In addition to these acute effects on agricultural land and aquatic environment, heavy metals, if proven to be present, will be released into the environment and into the food chain with possible long-term impacts on human health.

Toxicity levels

Due to some conflicting results of analyses conducted by local authorities, local universities and the UNDAC team, the main conclusion is that more research and monitoring of the quality of the mud is needed before final statements can be made on the toxicity of the mud. It is not determined whether the elevated levels of pollutants found by the local authorities are due to the natural composition or due to secondary pollution by, for example, the flooded industrial facilities in the affected area.
Some results that can be reported are:

- Media reports indicated the presence of phenols in the mud. None of the samples examined showed levels of organic compounds, including phenols, above normal expected background concentrations. Although the samples are not representative for the entire area of mud, there are no indications of significant deviations.

- Air samples and measured air quality do not show concentrations of organic compounds and specific toxic gasses (including hydrogen sulphide) above expected background concentrations.

- Based on samples and analysis, combined with existing data, indications exist that the mud content is not homogeneous. However, results of analysis performed by the UNDAC team and RIVM do not confirm this.

- Some samples taken and analyzed by the local authorities (and university) show elevated levels of toxins, such as heavy metals, including mercury. Samples and analysis performed by the UNDAC team and RIVM do not show elevated levels of organic compounds or heavy metals.

- Radiation has been measured at RIVM and proven to be of background level for all types of radiation (alpha, beta and gamma).

Other risks

Risks from recurrent toxic gas emissions, as well as earthquakes and subsidence, are unknown but cannot be excluded.

Existing measuring and monitoring capacity

The existing capacity for measurement and monitoring of air, mud and water quality is sufficient to provide appropriate information to the decision-making process in the emergency response activities. However, there is a clear need for increased coordination and interpretation of data. There are many actors involved in sampling and measurement (i.e., KLH, ITS, Airlangga University, Agricultural entities, public works entities) but an agreed monitoring and analysis programme has not been established, resulting in incomparable data and possible misinterpretation. This poses a serious risk for decision-makers.

Recommendations

Listed below is a summary of the recommendations. Each of these points is explained on the pages below:

- reinforce above-ground basins
- strengthen coordination, analysis and interpretation capacity
- develop a medium term strategy
- determine re-usability of the mud
- continue to monitor humanitarian impact.

Reinforce above-ground basins

Enforcement of existing above-ground mud basins is urgently needed to prevent damage and dispersion caused by collapse. If the existing dam walls prove to be too weak to contain the mud, there is an urgent need for enforcement of the dam walls in order to maintain the high-level of containment (and therefore low exposure).

Strengthen coordination, analysis and interpretation capacity

The environmental authorities should strengthen their capacity for coordinating, analysing and interpreting the analyses focusing on the following critical parameters: heavy metals (in particular mercury) and salinity/conductivity (as indicator for the dispersion of mud). To achieve this, the following steps should be undertaken.

Step	Action
1	Agree on a method to obtain representative samples from the large surface area. For example: a) divide all above-ground basins into imaginable rosters of 12 blocks of equal size. b) take an equal number of samples from each roster block and mix to obtain a representative sample from each roster block.
2	Mix the representative samples from each block to obtain a representative sample from the entire basin. **Note:** Although this is a standard and preferred way, the emergency situation and difficulties reaching central areas in the basin could allow mixing the entire basin using pumps and taking fewer samples.

Step	Action
3	Carry out a Robins test to verify the types of substances measured. **Note:** For a Robins test, the environmental authorities should have the same blind sample analyzed by all entities involved and coordinate the agreement of methodology to be used for future analysis.

Develop a medium term strategy

There is an urgent need to develop a medium term strategy – parallel to the ongoing emergency response - based on a number of options, including a worst-case scenario. The environmental authorities should carry out a full and detailed environmental impact assessment of all options for mud management as soon as possible, involving local expertise and integrating humanitarian and social impacts. The next section outlines some possible scenarios for re-use and disposal of the mud.

Determine reusability of the mud

Measurements for radioactive isotopes (such as uranium and thorium) should be undertaken to determine the re-usability of the mud. Radioactive isotopes could occur as Naturally Occurring Radioactive Materials and are associated with geological formations.

Monitor humanitarian impact

It is recommended that the UN agencies, through the UN Technical Working Group for Disaster Risk Reduction (UN TWG) continue to monitor the humanitarian impact of this mudflow on the affected population. In the event that the situation worsens, affecting larger numbers of people in the area, the UN TWG, together with the Government of Indonesia, should quickly mobilize teams to assess the situation and determine the scope of a UN and/or international assistance intervention.

4 Future Outlook and Indicative Risk Assessment

As a first step towards developing medium term strategies, as well as providing guidance on possible options for re-use of the large quantities of mud, scenarios have been roughly developed in an attempt to identify the environmental impacts of different options.

The scenarios include discharging into the aquatic environment (river and marine) and exposure of agricultural land to the mud. Annex II provides further details on the possible options for mud management.

Marine environment exposure

The aquatic environment can be exposed to the mud for example, if a decision is made to deposit the mud at sea. This situation would occur in the event of a dam collapse or overflow, as the sea is located only few kilometres from the source. The mud would follow natural gravity and be transported via rivers to the sea (if no preventive measures are taken).

Impact

Numerous fish ponds are situated in the coastal zone. Apparently the marine environment, including former mangroves, has been degraded by the aquaculture activities. The table on the following page provides an overview of expected impacts.

Agricultural land exposure

The mud is characterized by high salinity (comparable to sea water). Release of mud with high salt content onto agricultural land can have a severe effect on the crops. However, more detailed research should still be conducted by local experts to assess other possible adverse effect of the mud disposal on agricultural fields. The table on page 24 provides an overview of expected impacts.

Impact of exposure of the MARINE environment

Component	Critical parameter	Impact	Quantity/Concentration	Hazard- to the receptor	Exposure of ecosystem	Exposure of humans
Mud	Heavy metals	MEDIUM	MEDIUM Local elevation of heavy metals and especially mercury. Exceeding of Dutch and Indonesian water quality standards. Long term effects expected	HIGH High Toxic solids (mercury).	Possible fate of pollutants not assessed	MEDIUM Through bioaccumulation and bio concentration humans will be exposed by consumption of seafood.
Mud	Organic compounds, including Phenols	LOW	LOW Normal background concentrations detected.	HIGH Toxic	LOW Not applicable	LOW Not applicable
Mud	Salinity	LOW	HIGH Concentrations expected to be high	LOW Concentrations do not differ from sea water	LOW Not applicable	LOW Not applicable
Mud	Suspended solids	HIGH	HIGH The suspended solids are composed of more than 90% of clay	HIGH Suspended solids are dangerous for benthic organism and fishes (creation of anaerobic condition on the sea floor and clogging of fish gills)	HIGH Mud flow dilution is not expected to take place at the discharge point because of the difference of density between the mud and the sea water. The mud will rapidly cover the sea bottom and eradicate the existing benthic organisms and disturb the whole food chain	Not applicable

The mud is characterized by high turbidity (sediments) and possible creation of anaerobe (no oxygen) conditions. Sudden release of the mud into an aquatic environment will result in 'killing' the aquatic ecosystem and have serious implications for those people dependent on these ecosystems. In addition to these acute effects on agricultural land and aquatic environment, heavy metals, if proven to be present, will be released into the environment and into the food chain with possible long-term impacts on human health.

Aquatic environment of river systems exposure

Component	Critical parameter	Impact	Quantity/Concentration	Hazard- to the receptor	Exposure of ecosystem	Exposure of humans
Mud	Heavy metals	MEDIUM	MEDIUM Local elevation of heavy metals and especially mercury. Exceeding of Dutch and Indonesian water quality standards. Long term effects expected	HIGH Highly toxic solids (mercury).	Possible fate of pollutants not assessed	MEDIUM Through bioaccumulation and bio concentration humans will be possibly exposed by consumption of fishes
Mud	Organic compounds, including Phenols	LOW	LOW Normal background concentrations detected.	HIGH Toxic	LOW Not relevant	LOW Not applicable
Mud	Salinity	HIGH	HIGH Concentrations expected to be high	HIGH The fresh water body ecosystem are extremely sensitive to change in salinity	HIGH Fresh water living organisms will be eradicated by the discharge of a huge volume of salty water in their environment	Not applicable
Mud	Suspended solids	HIGH	HIGH The suspended solids is composed of more than 90% clay	HIGH Suspended solids are dangerous for benthic organism and fishes. (Creation of anaerobic condition on the river bed and clogging of fish gills)	HIGH	Not applicable

The results of ITS mud analysis indicate high concentrations of nitrite, ammonium and sulphite. However, due to time constraints the validity of the analytical method used were not assessed and the results interpretation was not completed. Since the turbidity and physical characteristics of the mud are estimated to be deathly for the ecosystem the possible presence of additional components, favouring anaerobe condition do not change the impact on aquatic environment that has already been predicted. Heavy metals, if proven to be present, will be released into the environment and into the food chain with possible long-term impacts on human health.

Impact of exposure of the agriculture lands

Component	Critical parameter	Impact	Quantity/Concentration	Hazard- to the receptor	Exposure of ecosystem	Exposure of humans
Mud	Heavy metals	MEDIUM	MEDIUM Local elevation of mercury slightly exceeding the Dutch sludge standards for agricultural use as organic fertilizer. Also slightly exceeding the Dutch ecological and human risk standards of soil quality.	HIGH Highly toxic solids (mercury).	LOW Slightly exceeding the ecological standards for the disposal of 2 tons of mud per ha and per year	MEDIUM Through bioaccumulation and bio concentration humans can be exposed by consumption of rice and vegetables
Mud	Organic compounds, including Phenols	LOW	LOW Normal background concentrations detected.	HIGH Toxic	LOW Not relevant	LOW No adverse effects expected
Mud	Salinity	HIGH	HIGH Concentrations expected to be high	HIGH Concentrations expected to be high	HIGH The crop will be severely affected by the salinity because the concentration of Na will exceed the coping capacity of the vegetation	Not applicable

The mud is characterized by high salinity (comparable to sea water). Release mud with high salt content onto agricultural land can have a severe effect on the crop. However, more detailed research should be conducted by local experts to assess other possible adverse effect of the mud disposal on agricultural fields.

Annex I: Sampling, Analysis and Results of the Impact Screening Carried Out By the UNDAC Team and RIVM/VROM.

Introduction

Prior to designing a sampling strategy, the UNDAC team first reviewed the sampling and analyses already conducted by local actors. UNDAC based its analysis on what it could add to the work already done and available equipment and expertise. The analysis of UNDAC samples was partly done by one of the team members using the facilities of the Indonesian Ministry of Environment and partly at the Dutch National Institute of Public Health and Environment in the Netherlands (RIVM). Based on available resources and data, the UNDAC team agreed to undertake the following tasks:

1. Perform a complete investigation (information gathering, sampling, analysis and consolidation) to determine an independent environmental impact assessment. **Note:** Priority was given to the part of the investigation that where not covered by the existing response. The activities include: Identification of the organic and inorganic compounds present in the mud and air (sampling and analysis) of the emission point and at the locations where the population is exposed (detailed description of the research strategy, methodology is provided in this annex).
2. Measure radiation levels in the mud (alpha, beta and gamma radiation).
3. Supervise the analysis of organic compounds in mud samples taken by KLH.
4. Identify and interpret the results of samples with high heavy metal contents (ITS).
5. Interpret the results according to the Dutch water-, sludge- and soil standards. **Note:** The Dutch water quality standards add to the currently used Indonesian standards of “discharge water into surface waters”. No sludge or soil standards were available. The intended use, discharge or disposal of the mud determents what standards should be applied (water, sludge of soil).
6. Perform at RIVM a full scan and identification of organic and inorganic substances in the mud and air samples taken by the UNDAC team for cross referencing.
7. Interpret the results and overall impact assessment.

Sampling strategy

The following sampling strategy was applied to identify the (potential) impact on the population and the environment.

Impact of the current situation can be estimated by reviewing the possible danger (characteristics and toxicity of substances present), the quantity and the exposure of the main receptors using the following formula.

IMPACT = QUANTITY x HAZARD x EXPOSURE of receptor

The two main receptors for which the hazard, quantity and exposure need to be evaluated are:
- the population that is potentially exposed to the mud and
- air originating from the mud volcano and the local environment (soil and water).

Impact of air pollution

The hazard, quantity and exposure of the mud was estimated by type and concentration of the substances present in the ambient air at the location where the population is exposed (receiving point) and where mud/slurry is emitted by the mud volcano. In practical terms this means the emission of hazardous substances in the air (directly from the source and from the mud) were identified and quantified.

Emissions of H_2S, aromatic carbons, SO_2 were expected. In order to both identify the hazardous substances present and to monitor the possible exposure of the population, different sampling techniques were used, varying in sampling time. The techniques used ranged from instantaneous sampling and handheld measurement equipment (to identify the present substances and concentrations at a certain time), to passive sampling badges providing information about the average concentration - over a period of several days. An overview of the sampling activities is provided in Table AppIV-1. Table AppIV-2 provides a detailed list of the sampling activities.

Impact of the mud

The hazard, quantity and exposure of the mud were estimated by type and concentration of the substances present in the mud. This estimation was done at the source (for clear identification purpose) and at the location of possible exposure (where population or specific environments can be in contact with the mud) In practical terms this means the hazardous substances possibly present in the mud were identified and quantified. In addition to hazardous substances the physical characteristics of the mud that can pose a threat to man and/or the environment e.g. radiation, suspended solid and salinity were identified.

Table AppIV-1 Overview of samples and results

Location 1 *(coordination: 07 32 003" S / 112 42 42.9" E)*			
		Analysis Concentration	
Description location	Compartment / type of sample	Organics	Heavy metals and gasses
Potential exposure of population	***Air***		
	Canister	<DL	-
	Charcoal tubes	background	-
	3M Badge	background	-
	Handheld measurement equipment	background	background
	Mud	background	background
Location 2 (*coordination : 07 31 369" S / 112 428" E)*			
Source	***Air***		
	Canister	<DL	-
	Charcoal tubes	background	-
	3M Badge	background	-
	Handheld measurement equipment	background	background
	Mud	background	background
Location 3 (*coordination: 07 32 008 S / 112 42 448 E)*			
Reference location	***Air***		
	Canister	<DL	
	Charcoal tubes	background	
	Handheld measurement equipment	background	background
	Soil	background	background

<DL: Below detection limits.

Summary of results from analysis undertaken at RIVM, the Netherlands

- Heavy metals in mud: All low, most of them like normal background values.
- Organic compounds in air (by handheld measurement devices, active and passive samplers): concentrations of benzene and toluene elevated at the source and the "exposure" location. Also Xylenes and hydrocarbons are elevated. Based on the spectrum of this different components and the fact that the "upwind" reference sample contains the same spectrum (although lower concentrations) we draw the conclusion that this components do not originate from the mud. Near to the sampling sites human activities take place (digging, pumping of mud, traffic) that allow this concentrations in air of substances in this respective spectrum to occur. The upwind location was influenced less by this kind of activities. No hydrogen sulphide (H_2S) was measured.
- Organic compounds in mud: no major elevations were detected nor expected based on components in air (volatile substances would be found in air as well if present).
- Radiation: normal background values or even below detection limits for all types of radiation.

Locations and analysis

Detailed results for each sampling location are presented in table AppIV-2 below.

Table AppIV-2. UNDAC samples and measurements

Location 1: Potential exposure of population *(coordination: 07 32 003" S / 112 42 42.9" E)*					
			Sampling time [hr]		
Sample technic	Sample date	Sample code	start	end	Remarks
Canister	29-jun-06	1	12:00	1:30	
	29-jun-06	2	12:00	1:30	
	30-jun-06	5	14:00	15:30	
	30-jun-06	6	14:00	15:30	
Charcoal tubes	29-jun-06	1A	12:00	14:00	
	29-jun-06	1B	12:00	14:00	break through tube of 1A
	29-jun-06	2A	12:00	14:00	
	29-jun-06	2B	12:00	14:00	break through tube of 2A
	30-jun-06	5A	14:00	16:00	
	30-jun-06	5B	14:00	16:00	break through tube of 5A
	30-jun-06	6A	14:00	16:00	
	30-jun-06	6B	14:00	16:00	break through tube of 6A
Mud	29-jun-06	1	12:00		
	29-jun-06	2	12:00		
3M Badge	29-jun-06	1	29-jun-06 12:35	1-jul-06 0:00	coordination: 07 32 003" S / 112 42 42.9" E (lost)
	29-jun-06	2	29-jun-06 12:35	1-jul-06 0:00	coordination: 07 32 003" S / 112 42 42.9" E (lost)
	29-jun-06	3	29-jun-06 12:40	1-jul-06 11:10	coordination: 0732003 S / 11242429 E 07 32 008 S / 112 42 44.8 E
	29-jun-06	4	29-jun-06 12:45	1-jul-06 11:10	coordination: 0732003 S / 11242429 E 07 32 00.3 S / 112 42 42.9 E
	29-jun-06	5	29-jun-06 12:45	1-jul-06 11:15	coordination: 0732003 S / 11242429 E 07 32 01.2 S / 112 42 46.2 E
	29-jun-06	6	29-jun-06 12:50	1-jul-06 11:15	coordination: 0732003 S / 11242429 E 07 32 02.6 S / 112 42 46.8 E
	30-jun-06	9	30-jun-06 14:00	1-jul-06 11:15	coordination: 07 32 003" S / 112 42 42.9" E
	30-jun-06	10	30-jun-06 14:00	1-jul-06 11:15	coordination: 07 32 003" S / 112 42 42.9" E
					coordination: 07 31 36.9 S / 112 42 8 E

Table AppIV-2. UNDAC samples and measurements, contd.

Location 2: Source (*coordination : 07 31 369" S / 112 428" E)*					
Charcoal tubes (SKC)	29-6-06	3A	16:00	18:00	
	29-6-06	3B	16:00	18:00	break through tube of 3A
	29-6-06	4A	16:00	18:00	
	29-6-06	4B	16:00	18:00	break through tube of 4A
Mud	29-6-06	3	16:00:00		+/- 15 cm deep
	29-6-06	4	16:00:00		+/- 15 cm deep
	3-7-06	5	11:30:00		+/- 15 cm deep
	3-7-06	6	11:30:00		+/- 15 cm deep
3M badge		7	29-jun-06 16:00	1-jul-06 13:00	coordination: 07 31 36.9 S / 112 42 8 E
		8	29-jun-06 16:00	1-jul-06 13:00	coordination: 07 31 36.9 S / 112 42 8 E
Location 3: Reference location/ nu mud influence (*coordination: 07 32 008 S / 112 42 448 E)*					
Canister	3-jul-06	7	10:45	12:45	
	3-jul-06	8	10:45	12:45	
Charcoal tubes	3-jul-06	7A	10:45	12:45	
	3-jul-06	7B	10:45	12:45	
	3-jul-06	8A	10:45	12:45	
	3-jul-06	8B	10:45	12:45	
Soil (reference)	3-jul-06	7	11:30		
	3-jul-06	8	11:30		

Dry weight of the mud

Dry weight of the mud was measured to compare the results with soil standards (fractions of pollutants in ug/kg-dry substance). The mud was dehydrated at 40 degrees Celsius. The dry weight contents of the mud samples are provided in Table AppIV-3 below.

Table AppIV-3. Dry weight of the mud

Sample number	**Dry weight kT-40, fraction dry matter of total**
13:15Z	0,54
3+4	0,45
5+6	0,46
7	0,79
8	0,79
5+6	0,90
5+6	0,89

Note: The mud consists of very fine clay particles that settle and dry slowly.

Analysis of inorganic compounds in the mud

Analysis of chlorate, nitrate and sulphate

Chlorate, nitrate and sulphate were analyzed using an ion chromatographic method. **Note:** Ions are separated by bringing the samples into a fluid flow and lead through a column with an ion switch. The ions are then measured by conductivity detection after chemical suppression.

Analysis of Phosphate (ortho-P)

Phosphate was analyzed using an automatic photometer. **Note:** The sample was mixed with a solution of molybdaat, antimony and ascorbinacid, as a result a blue coloured antimony fosformolybdatcomplex formed. The extinction was measured at 800 nm to detect the present quantity orthophosphate.

Analysis of Ammonium

Ammonium was analysed by Berthelot response: ammonia is chlorinated to monochloramine. After oxidation a blue-green complex is formed. The ammonium was measured by absorption at 660 nm.

Table AppIV-4a Inorganic compounds in mud

Sample name	Cl in mg/l	NH4 in mg/l	NO3 in mg/l	SO4 in mg/l	PO4 in mg/l	Conductivity uS/cm
Mud 2 Oost-Java 13:15	624,9	4,48	0,000	0,224	0,2990	2065
Mud 3+4 Mix	876,9	5,96	0,000	6,308	0,0466	2708
Mud 5+6 mix	1264,8	6,765	0,000	17,721	0,0218	3766
Soil 7	5,1	0,061	0,064	11,023	1,3449	123,2
Soil 8	7,7	0,101	0,643	13,685	1,4397	119,9

Analysis of heavy metals

The samples were deconstructed using aqua regia (nitrohydrochloric acid) following Inductively Coupled Plasma Mass Spectrometry (ICP-MS) analyses of the heavy metals.

Table AppIV-4b, concentrations of metals in the mud

Sample number	7 Li µg/g	9 Be µg/g	23 Na mg/g	26 Mg mg/g	27 Al mg/g	31 P mg/g	39 K mg/g	44 Ca mg/g	49 Ti µg/g	51 V µg/g	52 Cr µg/g	57 Fe mg/g	55 Mn µg/g
Detection limit ->	0,4	0,2	0,5	0,10	0,02	0,12	0,4	0,3	1	6	2	0,2	8
mud 2	44,1	1,1	10,3	10,85	70,85	0,45	8,5	13,8	528	93	34	41,8	823
mud 2	48,9	1,0	10,1	10,70	70,78	0,45	8,8	14,4	573	99	37	45,6	907
mud 3+4	46,1	0,8	13,0	9,73	38,78	0,39	4,8	10,3	78	51	25	37,7	720
mud 3+4	64,2	1,3	14,1	11,27	69,78	0,40	9,4	11,5	343	86	42	43,0	803
mud 5+6	65,9	1,1	20,9	12,10	76,41	0,39	10,0	11,9	448	91	42	41,8	795
mud 5+6	66,0	1,0	19,4	11,12	60,44	0,37	7,9	11,8	247	78	40	42,4	835
soil 7	7,1	0,2	5,4	3,91	64,80	0,44	0,9	42,0	1943	115	9	39,6	634
soil 8	8,6	0,5	5,6	4,17	69,68	0,41	1,1	41,1	2246	130	11	45,1	769

Sample number	60 Ni	59 Co	65 Cu	66 Zn	75 As2	88 Sr	114 Cd	121 Sb	137 Ba	202 Hg	205 Tl	208 Pb
	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	ng/g	µg/g	µg/g
Detection limit ->	1,0	0,2	1,2	8	4	2,4	0,08	0,10	2	**0,001**	0,06	0,4
mud 2	19,6	14,1	24,2	82	5,4	282	<AG	0,48	111,5	14	0,48	17,8
mud 2-duplo	20,5	15,3	24,5	81	6,8	283	0,13	0,45	110,8	15	0,41	15,9
mud 3+4	18,6	12,9	15,9	80	7,9	290	0,10	0,28	45,5	9,9	0,21	13,5
mud 3+4-duplo	22,7	14,5	17,4	78	7,4	301	0,09	0,36	81,9	10	0,38	13,5
mud 5+6	21,7	13,9	17,4	79	8,6	361	<AG	0,41	96,1	9,4	0,40	18,8
mud 5+6-duplo	22,6	14,4	17,7	76	7,5	338	<AG	0,30	68,7	9,6	0,32	13,5
Soil 7	7,1	13,4	33,1	67	3,0	295	0,08	0,22	175,2	20	0,10	10,9
Soil 8	12,6	15,3	37,0	70	2,0	289	<AG	0,21	186,2	16	0,09	10,9

Organic compounds in the mud

Organic compounds in mud were analyzed in Indonesia. No major elevations of organic compounds were found nor were indications found in the analysis of the air besides the mud that high concentrations of organic compounds would be present.

Air measurements (using handheld measurement devices)

Using handheld measurement equipment, a direct reading of the concentrations at the sampling moment and location were provided. The equipment measured specific components individually. The results of the measurements are not highly accurate and are only useful for screening purposes, personal protection and first impressions. The components measured during several points in time and locations (during all other sampling occasions) were:

- Total hydrocarbons with photo ionisation detector (multi PID2)
- H_2S, NH^3, SO^2, HCN, CO, CO^2, O^2 en PH^3 using electrochemical cells
- Combustible gasses using an explosion alarm monitor.

No unexpected elevations were noted during the various measurements.

Analysis of organic compounds in the air (using canisters)

Canisters were used with a flow reduction valve to obtain a continuous sampling period of two hours. Using this technique, high peak concentrations can be measured in a the relatively short sampling time. Samples with canisters are often taken at locations and times where the handheld equipment indicates high concentrations. The results are useful for providing insight into the exposure of a population to possible peak concentrations occurring over short periods. Analysis of the sampled air was completed at the laboratory using GC-MS techniques that allow identification of compounds and accurate quantitative analysis.

Notes: In addition to the charcoal tubes and passive samplers, these canisters allow analysis of the air without the use of an absorbent substance (such as charcoal). Without an absorbent to trap and absorb the components, possible inaccuracies are eliminated. Due to the relatively small quantities of air analyzed, the detection limits are higher in comparison to analyses of samples taken with charcoal tubes and passive samplers.

Table App. V-a, Organic compounds in air sampled by canisters, analysed at RIVM in the Netherlands

	Concentration ug/m3		
Sample/canister number	1	2	5
PH3	<	<	
Vikane	<	<	
Dichlorodifluormethaan_(CFK12)	<	<	
Chloromethaan_(Methylchloride)	<	<	<
Chloroetheen_(Vinylchloride)	<	<	<
Dichlorotetrafluorethaan_(CFK114)	<	<	<
Methylbromide	<	<	<
1,3-Butadieen	<	<	<
Trichlorofluormethaan_(CFK11)	<	<	<
1,1-Dichloroetheen	<	<	<
Chloroethaan	<	<	<
Dichloromethaan_(Methyleenchloride)	<	<	<
1,1,2-Trichlorotrifluorethaan_(CFK113)	<	<	<
1,1-Dichloroethaan	<	<	<
cis-1,2-Dichloroetheen	<	<	<
Trichloromethaan_(Chloroform)	<	<	<
3-Chloropreen	<	<	<
Tetrachloromethaan	<	<	<
Trichloroetheen_(Tri)	<	<	<
1,1,1-Trichloroethaan	<	<	<
1,2-Dichloroethaan	<	<	<
Benzeen	<	<	<
Tetrachloroetheen_(Tetra)	<	<	<
cis-1,3-Dichloropropeen	<	<	<
Chloropicrine	<	<	<
1,2-Dichloropropaan	<	<	<
trans-1,3-Dichloropropeen	<	<	<
1,1,2-Trichloroethaan	<	<	<
1,2-Dibromoethaan	<	<	<
Tolueen	30	<	<
Chlorobenzeen	<	<	<
1,1,2,2-Tetrachloroethaan	<	<	<
Ethylbenzeen	<	<	<
Styreen	<	<	<
1,2-Dichlorobenzeen	<	<	<

	Concentration ug/m3		
Sample/canister number	1	2	5
1,3-Dichlorobenzeen	<	<	<
m/p-Xylene	<	<	<
o-Xyleen	<	<	<
1,4-Dichlorobenzeen	<	<	<
4-Ethyltolueen	<	<	<
1,3,5-Trimethylbenzeen	<	<	<
1,2,4-Trichlorobenzeen	<	<	<
1,2,4-Trimethylbenzeen	<	<	<
1,1,2,3,4,4-Hexachloro-1,3-butadiene	<	<	<

< = below 25 ug/m3

	Concentration ug/m3		
Sample/canister number	6	7	8
PH3	<	<	<
Vikane	<	<	<
Dichlorodifluormethaan_(CFK12)	<	<	<
Chloromethaan_(Methylchloride)	<	<	<
Chloroetheen_(Vinylchloride)	<	<	<
Dichlorotetrafluorethaan_(CFK114)	<	<	<
Methylbromide	<	<	<
1,3-Butadieen	<	<	<
Trichlorofluormethaan_(CFK11)	<	<	<
1,1-Dichloroetheen	<	<	<
Chloroethaan	<	<	<
Dichloromethaan_(Methyleenchloride)	<	<	<
1,1,2-Trichlorotrifluorethaan_(CFK113)	<	<	<
1,1-Dichloroethaan	<	<	<
cis-1,2-Dichloroetheen	<	<	<
Trichloromethaan_(Chloroform)	<	<	<
3-Chloropreen	<	<	<
Tetrachloromethaan	<	<	<
Trichloroetheen_(Tri)	<	<	<
1,1,1-Trichloroethaan	<	<	<
1,2-Dichloroethaan	<	<	<
Benzeen	<	<	<
Tetrachloroetheen_(Tetra)	<	<	<
cis-1,3-Dichloropropeen	<	<	<
Chloropicrine	<	<	<
1,2-Dichloropropaan	<	<	<
trans-1,3-Dichloropropeen	<	<	<
1,1,2-Trichloroethaan	<	<	<
1,2-Dibromoethaan	<	<	<
Sample/canister number	6	7	8

	Concentration ug/m3		
Tolueen	<	<	<
1,1,2,2-Tetrachloroethaan	<	<	<
Ethylbenzeen	<	<	<
Styreen	<	<	<
1,2-Dichlorobenzeen	<	<	<
1,3-Dichlorobenzeen	<	<	<
m/p-Xylene	<	<	<
o-Xyleen	<	<	<
1,4-Dichlorobenzeen	<	<	<
4-Ethyltolueen	<	<	<
1,3,5-Trimethylbenzeen	<	<	<
1,2,4-Trichlorobenzeen	<	<	<
1,2,4-Trimethylbenzeen	<	<	<
1,1,2,3,4,4-Hexachloro-1,3-butadiene	<	<	<
	<	<	<

< = below 25 ug/m3

Analysis of organic compounds in the air (using charcoal tubes)

Charcoal tubes were used with a calibrated pump to sample a continuous flow during a required sampling period (several hours). After absorption of the trapped air pollutants, analysis of the components was conducted at the laboratory using GC-MS techniques allowing identification of components and highly accurate quantitative analysis. **Note:** Due to the relatively large quantities of air sampled, the detection limits are low.

Table App. VI-a, Organic compounds in air sampled by charcoal tubes, analysed at RIVM in the Netherlands

Concentrations of standard reference components in ug/m3 air

Sample number of tube	1a	1b	2a	2b	3a	3b	4a	4b	6a	6b	7a	7b	8a	8b
hexaan	3	< 1	3	< 1	1	< 1	1	< 1	2	< 1	1	< 1	1	< 1
trichloromethaan	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,2-dichloroethaan	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,1,1-trichloroethaan	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
benzeen	16	< 1	15	< 1	15	< 1	14	< 1	26	< 1	6	< 1	5	< 1
tetrachloromethaan	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1
1,2-dichloropropaan	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
trichloroetheen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
heptaan	3	< 1	3	< 1	< 1	< 1	< 1	< 1	2	< 1	< 1	< 1	< 1	< 1
1,1,2-trichloroethaan	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
tolueen	20	< 1	18	< 1	11	< 1	10	< 1	17	< 1	7	< 1	6	< 1
tetrachloroetheen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
octaan	3	< 1	2	< 1	< 1	< 1	< 1	< 1	2	< 1	< 1	< 1	< 1	< 1
chloorbenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Concentrations of standard reference components in ug/m3 air

ethylbenzeen	2	< 1	2	< 1	1	< 1	1	< 1	2	< 1	5	< 1	4	< 1
m-xyleen	3	< 1	3	< 1	3	< 1	3	< 1	5	< 1	3	< 1	3	< 1
p-xyleen	1	< 1	1	< 1	2	< 1	1	< 1	2	< 1	1	< 1	1	< 1
o-xyleen	2	< 1	2	< 1	2	< 1	2	< 1	3	< 1	2	< 1	1	< 1
nonaan	2	< 1	2	< 1	< 1	< 1	< 1	< 1	2	< 1	< 1	< 1	< 1	< 1
cumeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
propylbenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4-ethyltolueen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3-ethyltolueen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,3,5-trimethylbenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2-ethyltolueen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,2,4-trimethylbenzeen	1	< 1	1	< 1	2	< 1	1	< 1	2	< 1	1	< 1	1	< 1
1,3-dichlorobenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,4-dichlorobenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
decaan	2	< 1	2	< 1	1	< 1	< 1	< 1	2	< 1	1	< 1	< 1	< 1
1,2,3-trimethylbenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,2-dichlorobenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
cymeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
limoneen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
butylbenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
undecaan	2	< 1	2	< 1	1	< 1	1	< 1	2	< 1	1	< 1	1	< 1
1,3,5-trichlorobenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,2,4-trichlorobenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,2,3-trichlorobenzeen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
dodecaan	2	< 1	2	< 1	1	< 1	1	< 1	3	< 1	1	< 1	1	< 1
tridecaan	2	< 1	2	< 1	1	< 1	1	< 1	3	< 1	1	< 1	1	< 1
tetradecaan	2	< 1	2	< 1	1	< 1	1	< 1	4	< 1	1	< 1	1	< 1
pentadecaan	2	< 1	2	< 1	1	< 1	1	< 1	5	< 1	2	< 1	2	< 1
hexadecaan	1	< 1	1	< 1	1	< 1	1	< 1	5	< 1	1	< 1	1	< 1
styreen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
naftaleen	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1	2	< 1	< 1	< 1	< 1	< 1
2-methylnaftaleen	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	2	< 1	< 1	< 1	< 1	< 1

Concentrations of components outside standard reference set* in ug/m3 air

Sample number	1a	
CAS nr.	Name	µg/m3
96140	>Pentane, 3-methyl-	1
96377	>Cyclopentane, methyl-	1
110827	>Cyclohexane	1
108872	>Cyclohexane, methyl-	2
591219	>1,3-Dimethylcyclohexane,c&t	1

Concentrations of components outside standard reference set* in ug/m3 air

Sample number	2a	
CAS nr.	Name	µg/m3
96140	>Pentane, 3-methyl-	1
96377	>Cyclopentane, methyl-	1
110827	>Cyclohexane	1
108872	>Cyclohexane, methyl-	2
591219	>1,3-Dimethylcyclohexane,c&t	1

*Concentrations of compounds outside the standard reference set are calculated based on the response of toluene. The results are therefore not of the highest accuracy but are valid to be used as indications.

Analysis of organic compounds in the air (using passive samplers)

Passive samplers were used to sample the air during a long period (often chosen to be several days). The resulting average concentrations during these longer periods allow good insight in the average exposure of the population. After absorption of the trapped air pollutants, analysis of the components was conducted at the laboratory using GC-MS techniques allowing identification and highly accurate quantitative analysis. **Note:** Due to the relatively large quantities of air sampled, the detection limits are low.

Table App. VII, Organic compounds in air sampled by passive samplers, analysed at RIVM in the Netherlands

Concentrations of standard reference components in ug/m3 air	3	4	5	6	7	8	9	10
Sample number of badge	3	4	5	6	7	8	9	10
hexaan	5	4	5	6	5	5	3	2
trichloromethaan	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,2-dichloroethaan	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,1,1-trichloroethaan	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
benzeen	23	21	24	28	27	25	15	15
tetrachloromethaan	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,2-dichloropropaan	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
trichloroetheen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
heptaan	3	3	4	4	4	4	2	2
1,1,2-trichloroethaan	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
tolueen	27	25	26	30	30	27	15	14
tetrachloroetheen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
octaan	2	2	2	3	3	2	< 2	< 2
chloorbenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
ethylbenzeen	4	3	3	4	4	4	< 2	< 2
m-xyleen	6	6	7	7	7	7	4	4
p-xyleen	< 2	< 2	2	2	2	2	< 2	< 2
o-xyleen	4	3	4	4	4	4	2	2
nonaan	3	3	3	3	3	3	< 2	< 2
cumeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
propylbenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
4-ethyltolueen	2	< 2	3	2	< 2	< 2	< 2	< 2

Concentrations of standard reference components in ug/m3 air	3	4	5	6	7	8	9	10
3-ethyltolueen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,3,5-trimethylbenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
2-ethyltolueen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,2,4-trimethylbenzeen	4	< 2	< 2	4	4	4	2	2
1,3-dichlorobenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,4-dichlorobenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Decaan	3	4	3	4	4	4	3	2
1,2,3-trimethylbenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,2-dichlorobenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
cymeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
limoneen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
butylbenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
undecaan	2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,3,5-trichlorobenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,2,4-trichlorobenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
1,2,3-trichlorobenzeen	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
dodecaan	5	5	3	3	5	3	2	< 2
tridecaan	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
tetradecaan	6	5	4	4	6	4	4	3
pentadecaan	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
hexadecaan	< 2	2	< 2	< 2	2	2	< 2	< 2

Concentrations of components outside standard reference set* in ug/m3 air

Sample number	6	
CAS nr.	Name	µg/m3
96140	>Pentane, 3-methyl-	2
96377	>Cyclopentane, methyl-	2
590738	>Hexane, 2,2-dimethyl-	2
108872	>Cyclohexane, methyl-	2
Sample number	7	
CAS nr.	Name	µg/m3
96140	>Pentane, 3-methyl-	2
96377	>Cyclopentane, methyl-	2
590738	>Hexane, 2,2-dimethyl-	2
108872	>Cyclohexane, methyl-	2
Sample number	8	
CAS nr.	Name	µg/m3
96140	>Pentane, 3-methyl-	2
96377	>Cyclopentane, methyl-	2
590738	>Hexane, 2,2-dimethyl-	2
108872	>Cyclohexane, methyl-	2

*Concentrations of compounds outside the standard reference set are calculated based on the response of toluene. The results are therefore not of the highest accuracy but are valid to be used as indications.

Analysis of radiation

Different kinds of radioactive decay

Radioactive isotopes can emit alpha particles, beta particles and gamma rays, depending on the isotope. Each have a different kind of interaction with the human body as briefly explained below.

Alpha particles: A positively charged particle emitted by certain radioactive material consisting of two neutrons and two protons, the nucleus of a helium atom. A dangerous carcinogen when inhaled or ingested. Alpha radiation can penetrate the body to just below the dead skin, but is blocked by clothing or even a sheet of paper. When released inside our bodies from material we inhale or swallow, alpha particles are able to transfer their energy at short range to damage body cells.

Beta particles: A beta particle is a single high-energy electron moving at high speed and carrying a negative charge. They can travel about one metre through air and can penetrate the skin, to reach internal tissue. Can cause skin burns and, when ingested, cancer. Beta rays are especially dangerous when emitted inside the body.

Gamma rays: Gamma rays are electromagnetic waves or photons emitted from the nucleus (center) of an atom. They have no electrical charge and penetrate deeply into the body, or pass through it, creating ions as they collide with atoms along their path. Gamma rays are similar to X-Rays, but are much more powerful.

Natural radioactivity in soil samples from Indonesia

Radioactive isotopes such as, Th-232, Ra-226 and K-40 are naturally present in all different types of soil, but the amounts vary considerably depending on the material. Many building materials, such as concrete and bricks, made from these soil materials and therefore also contain the same radioactive isotopes. These radioactive isotopes emit different kinds of radiation called alpha, beta and gamma radiation as mentioned above.

How much radioactivity is allowed in these building materials depends on where they are used, but requirements for protection to radiation are given in the EU Council Directive 89/106/EEC of 21 December 1988 relating to construction products (EC 1988). By order of the European Commission the Finnish Center for Radiation and Nuclear Safety (STUK) has made a study about natural radioactivity of building materials and in industrial by-products used as raw materials in building material industry (Mustonen et. al 1997).

STUK propose the introduction of an activity index used to assess the safety requirement of building materials. The proposed activity index is $I = (C_{Th}/200 + C_{Ra}/300 + C_K/3000)$, where C_{Th}, C_{Ra} and C_K are the activity concentrations of Th-232, Ra-226 and K-40, expressed in Bq/kg. If this value of the activity index is less than or equal to 1, the building material can be used for construction. However, if the value of the activity index exceeds 1, it is required to show specifically that the safety requirement will be met, and the indoor radon concentration of 200 Bq/m^3 due to the use of the material will not be exceeded. In March 1999, the EU Article 31 Group of Experts on Radiation Protection decided to publish the STUK report as Radiation Protection No. 95.

Analysis

To check whether the soil samples from Indonesia were low in radioactivity and therefore able to be used as raw material for bricks, analyses were performed on all 5 samples using different techniques (gammaspectrometry and total-alpha/total-beta analysis by liquid scintillation counting). The results are detailed in the table below.

Results

The results from the gammaspectrometric measurements are given in ***Table 2*** using the parameters given in ***Table 1***.The total-alpha and total-beta results are all below the detection limits of the method, being 300 and 2000 Bq/kg respectively.

Table 1: Relevant sample parameters

Sample id	A	B	C	D	E
Reference	13:15Z	3+4	5+6	7	8
Wet weight	142 gram	146 gram	338 gram	181 gram	150 gram
Dry fraction	53.58%	45.23%	40.54%	79.44%	78.93%
Dry weight	76.1 gram	66.0 gram	137.0 gram	143.8 gram	118.4 gram

Table 2: Results from gammaspectrometric measurements in Bq/kg

Sample id	A	B	C	D	E
Ra-226	49 ± 8	61 ± 10	21 ± 2	11 ± 5	19 ± 7
Th-232	48 ± 8	86 ± 10	35 ± 3	13 ± 4	22 ± 5
K-40	740 ± 140	580 ± 130	200 ± 30	180 ± 50	120 ± 40
Activity index	0.65 ± 0.07	0.83 ± 0.08	0.32 ± 0.02	0.16 ± 0.03	0.21 ± 0.04

Conclusions on radiation

The radioactivity in the soil samples analysed is below the recommendations as given by the EC and the soil material can therefore be used for making bricks. Additional results for e.g. heavy metals content can however make this soil material not suitable for further use after all.

References

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Annex II Possible Options for Mud Management

Based on information provided by the National Institute for Water Treatment in the Netherlands, there are a number of options for the management of the mud.

For each option, short descriptions of what is involved, the process and expected timeframes are provided in the table below.

Option	Involves	Process	Expected timeframe
Natural dewatering	Sedimentation by gravity.	Natural dewatering in depots in open air. A slow process, if possible, due to the small size of the particles in suspension.	At least one year.
Flocculation	Separation of the solid fraction from the water fraction.	Use of flocculants - substances that bind particles and increase their mass so that they will sink to the bottom. There are hundreds of types of flocculants and the right type and doses is determined by the characteristics of the mud (pH, temperature, etc).	Several months.
Vacuum extraction	Creating an ‘under pressure’.	Sucking water away from the bottom from a sufficiently high (deep) water basin –of at least 5 to 6 metres Treatment of such a large quantity of mud in deep basins poses serious challenges though.	Likely to lead to positive results within weeks to months.
‘Geotubes’	High quality textile shaped like long ‘sausages’, through which the mud can be inserted.	The textile functions as a filter to separate the water fraction from the solids while also supporting the containment of the solid fraction.	Could provide results in days/weeks.

Annex III Proposed Setup of Mud Quality Monitoring Programme

Introduction

A structured approach is advised to define and monitor the quality of the mud, and to consolidate and define actions based on the results. In this annex, a first draft of the design of such a programme is presented.

Defining the exact quality of the mud is of paramount importance. The possible options of disposal or reuse of the mud are highly dependent on the quality. With the first screening of the quality of the mud done by the local authorities (as described in the report) elevated levels of heavy metals were found in some samples, indicating that the mud that is already deposited is not of homogeneous quality. Samples taken by the UNDAC team and analyzed at RIVM in the Netherlands do not contain unexpected levels of (heavy) metals or organic compounds. Before reuse or disposal of the mud more insight into the quality is needed.

The first advised monitoring activity is to investigate if the source emits mud with high concentrations of heavy metals. If the mud from the source is proven to meet the soil, sludge and water quality standards, this material needs to be kept separate and secondary pollution needs to be prevented. More options of disposal or reuse are feasible if the mud is proven to meet the quality standards.

The second advised monitoring activity is aimed at defining the quality of the mud that is already deposited (surrounding mud). Since the current analysis by local authorities indicates that the quality of the surrounding mud differs between the different sampling locations (non-homogeneous) it must be defined which ponds meet certain quality standards and which ponds do not. Depending on the quality of the whole pond the options for reuse or disposal can then be defined. If disposal of the mud on the land (agricultural) is being considered as an option, the current quality of the receiving land needs to be monitored in order to determine if mud disposal is truly feasible.

If a significant impact of the mud on the surrounding environment is expected, then a third monitoring activity is advised. This would aim to detect if the mud or the water of the mud has entered the surrounding environment – using the salinity of the mud as an indicator. Measurements of conductivity (salinity) of the shallow wells and rivers compared to the normal values indicate the impact of the mud on the surrounding environment.

It is envisaged that the three different monitoring programmes can be carried out in parallel to speed up the process and make efficient use of the sampling and analytical capacity.

Monitoring Activity 1: Mud Source

Goal: To determine if the quality of the source material complies with the standards of water and sludge. The possible options of disposal or reuse depend on the quality of the mud.

Practice: Regular (daily or every other day) sampling and analysis of heavy metals and organic compounds. Regularly monitor naturally occurring radioactive isotopes.

Consolidation of the results and facts: This monitoring program is designed to determine which of the following conclusions about the quality of the source applies:

1. The heavy metal and organic compound concentrations of the mud directly from the source are below the water quality and soil/sludge standards.
2. The heavy metal and organic compound concentrations of the mud directly from the source exceed the water quality and soil/sludge standards.
3. The heavy metal and organic compound concentrations of the mud directly from the source are variable over time, i.e., on some days concentrations of heavy metal are above the standards and on other days concentration limits are met.

Decision making and actions:

If concentrations are below the standards, the emission from the source needs to be kept "clean" from secondary pollution. It should be directly processed as for "clean" mud, or transported (pumped) and contained in clean ponds for later use.

If concentrations exceed the standards or the concentration is variable, the following possible are available:

1. The mud should be contained in ponds and definitive analysis of the quality should to be conducted after mixing. The process of sampling and analysis strategy and follow up actions as described under the process of "surrounding mud".
2. Direct to a "polluted" deposit or reuse.

Monitoring Activity 2: Surrounding Mud

Goal: To determine if the quality of the material in different ponds that has already been deposited does not exceed the local background concentrations of possible receiving land.

A basic assumption in the risk assessment is that if the concentrations of contaminants in the mud are equal to or lower than the local background, then no additional risk is caused by the existence of the mud ponds

Practice: Based on an exploratory survey from the UNDAC team there is no reason to believe that the ponds induce additional risk due to elevated levels of metals and metalloids. The sampling scheme consisted of 4 samples, 3 random samples from within the ponds and one random sample outside the ponds. Due to the small amount of samples and the improvised sampling scheme, the results should be interpreted as qualifying rather then quantifying.

To answer the question whether the mud imposes additional risk to the surroundings qualitatively, a reconnaissance survey is needed. This survey should provide insight into the composition of the mud, the variability of this composition and how the composition compares with the local background. Using the knowledge of the exploratory survey, an uncomplicated survey would be proposed to verify the assumption that the mud does not impose any additional risk.

Since knowledge about the local background is imminent, sampling of both the ponds and the surroundings is needed. The amount of samples can be best determined by pragmatic judgment and available budget. However, the following 3 conditions are proposed as a guideline:

1) About one third of the samples should be assigned to the surrounding area.
To compare the composition of the local background a relevant amount of samples should be taken from the topsoil layer (0-10 cm) of the surrounding area. The sample location should be representative for typical soil types and land use. The amount of one third is arbitrary but guarantees that enough samples are collected to compare the variability of the concentrations with those from the ponds.

2) From each (large) pond at least 3 samples should be taken.
A minimum of three samples guarantee that for each pond, insight is obtained about the variance of the concentrations.

3) From the surrounding area at least 10 samples should be taken.
A good estimate of the local background is needed, without prior knowledge it is inferred that the arbitrary number of 10 samples should be enough to obtain this estimate.

Decision making and actions:
After analyses of the samples, the results of the surrounding area and the mud should be compared. Variability between the composition of the surrounding soil and the mud should be judged mainly based on geochemical relevance rather than on statistical significance.

If concentrations in the ponds are <u>below</u> the concentrations of the surrounding/receiving environment, the mud can be used or disposed of at these locations.

If the results give reason to believe that the concentrations of the mud are <u>elevated</u> in comparison with the surrounding soil, additional research is needed to assess the magnitude of the additional risk.

Annex IV: Follow-up Mission Report

Introduction

Following a request made by the Indonesian Ministry of Environment at the end of the UNDAC emergency mission on 27 July 2006, an environmental expert was redeployed to Indonesia. The government of Switzerland kindly provided the expert for this follow up mission.

It was agreed with the Indonesian Ministry of Environment that the expert would focus activities on environmental emergency management issues. This annex contains the results of the follow-up mission.

Approach

During the first part of the mission, intensive work sessions with the Ministry of Environment team were organized to:

- define the mission goal, objectives and expected outputs
- agree upon a strategy
- validate the expert proposals.

A field visit in Surabaya was organized to assess the evolution of the mud flow situation and the environmental emergency management activities. During this field visit, meetings were organized with scientists, engineers and senior local administration representatives.

At the end of the mission the Ministry of Environment was briefed about the outcome of the expert mission.

Findings

Mud flow

The mud continues to flow unabated from the same point. The day of the visit, the mud volcano was very active; seemingly more so than during an expert visit 3 weeks before. Unfortunately, the first attempt to stop the mud flow using the existing well and the "snubbing unit" has failed.

Dam reinforcement

The dam reinforcement has been completed for mud basins A and B and is progressing for basins C, 3 and 4. The reinforcement is mainly obtained by dumping earth (a mix of soil, clay and pebbles from unknown origin) on the pre-existing walls and levelling it until the desired height (up to 2 to 3 meters) and thickness (enough to accommodate a large truck) are reached.

Heavy earth moving machinery (lorries, earth scrapers, front end loaders) have been deployed to work on the dam walls.

No other techniques have so far been used to further improve the dam stability or to increase the impermeability of the wall surface.

Future mud treatment basin

Plans have been made to use the sugar cane fields adjacent to ponds 3 and 4 as mud treatment basins. To date no study has been conducted to assess the possible impact on the population and the environment of this activity which will most probably involve storage and use of large quantities of chemicals (flocculants, acid/bases for Ph control) and will certainly create a significant quantity of sludge or effluents.

New residential area flooded

A residential area, adjacent to the north limit of the C pond, has been recently (3 weeks ago approximately) flooded by the mud. The inhabitants (unknown number) were evacuated and accommodated in the Pasar Baru Porong (Market).

Visual risk assessment

There is no more than 10 metres between the existing dam wall built at the northern limit of the C pond and a densely populated residential area (composed mainly of individual houses and small shops). The mud level is already quite high in the pond and in some places is almost reaching the top of the containment. Since the wall is approximately 2 metres high, the population living close to it is clearly at risk. Casualties may result from a dam wall collapse.

Mud treatment and reuse

The authorities are currently considering mud treatment and reuse as the best solution for a safe disposal in the environment. The authorities are even offering new business opportunities, for example for the production of brick and building material.

At the time of the mission, there was no indication that a feasibility study has been conducted to assess the efficiency and viability of mud treatment.

Although theoretically feasible, these techniques are usually complicated, time consuming and expensive. Considering the quantity involved, it is far from certain that any treatment has the capacity to process enough mud in time to really eliminate the risk of an uncontrolled mud flow.

Impact on the environment

The scientists and engineers interviewed during the field visit confirmed that, if not properly planned and executed, the disposal of mud and salty and turbid water can seriously harm the populations and the environment. They also confirmed that, so far, no real impact assessment has been carried out. It appears that the authorities have only sought scientific advice and technical support in an “ad hoc” rather than an optimal way.

Conclusions and concerns

- There is no guarantee that the mud flow can be stopped.
- The risk of an uncontrolled mud release with serious consequences on the population and on the economy and environment is increasing.
- The arrival of the rainy season will probably exacerbate the existing problems and a sudden degradation of the situation can not be excluded.

The activities of the authorities and of the Ministry of Environment are mainly focused on response and in particular on mud containment. No clear strategies for handling the possible emergency situations which can result from a dam collapse or overflow have been established and the consequences of a possible uncontrolled mud flow have not been fully assessed (impacts quantification).

Recommendations

Emergency management

In parallel with current mud containment activities, a new local emergency management structure should be set up with a focus on preparedness and response planning.

As shown in the figure below, within this new structure, it is recommended that:

- A clear distinction between the roles and responsibilities of the parties involved be established.
- A pool of experts is established to scientifically assess the impact of the mud flow on the population and on the environment and propose integrated technical solutions to the decision makers.
- The emergency management authorities responsible for taking the decisions, base these on the experts advice and proposed solutions.
- A group of specialized companies with the appropriate technical skills and resources are recruited to implement the measures and actions decided by the emergency management authorities.

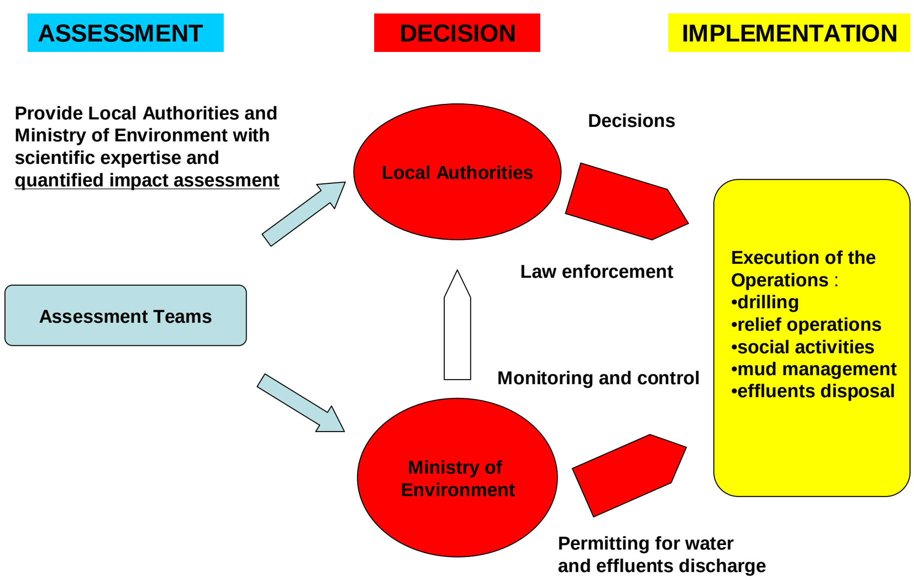

Figure 1. Emergency Management roles and functions

Multidisciplinary approach

As the different issues to be considered are complex (mud management, water discharge, possible population evacuation and resettlement) the scientific and risk assessment demands a multidisciplinary and coordinated approach as set out below.

Impact assessment

For each relevant issue, such as risk assessment, mud containment and mud/water disposal, a group of fours to five experts should be formed. Working under the coordination of an environmental generalist, each group should identify the:

- constraints posed by the mud flow
- potential risks for the populations and environment
- technical solutions to eliminate or minimize the impact of the mud flow on the population and environment.

Mud, water and air quality monitoring

Disposal into the environment of treated water and mud will require regular quality control and monitoring of the effluents.

For this purpose, laboratories with required equipment and trained staff should be selected and appointed to carry out the analysis (accredited laboratories).

Interpretation of the results and consolidation should be done by a qualified environmental chemist.

Overall coordination

The activities of both groups ("impact assessment" and "quality monitoring") should be coordinated by a senior environmental generalist as shown in the figure below. This person will also be responsible for the transmission of the scientific expertise and advice to the decision makers.

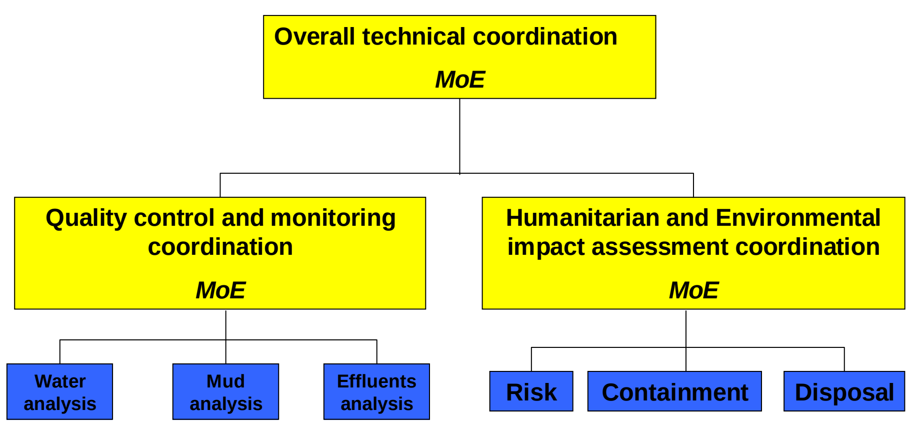

Figure 2. Impact assessment and quality monitoring structure

Most urgent issues

The priority for the impact assessment groups should be to focus their activities on the following issues:

- Technical survey of the dams to make sure that they have been properly build and that they will resist to the rainy season.
- Risk assessment of a possible dam collapse.
- Impact assessment of the effluent/mud discharge on the pond fish, marine ecosystem**.**
- Evaluation of the feasibility and efficiency of the possible water/mud treatments.

Note: A detailed description of these activities and an action plan is set out on the pages below.

Activities

Missions

- The task force should:
- assess the impact of the mudflow on the population and ecosystems
- assess the impact on the environment of all actions and activities undertaken to manage, control the mud flow and to mitigate its consequences (mud containment, mud and water disposal, by product generated by a possible mud treatment)
- develop and implement an environmental monitoring program (mud, water and effluents quality analysis and control).

Based on the impact assessment and on the monitoring activities, the task force should provide the decision makers with expert information, scientific advises and technical support.

Impact assessment activities

Impact assessment activities, including their topics, goals and objectives are provided in the matrix below.

Topics	Goals	Objectives
Mud containment	Assess the size of the area which should be used for building additional mud containment or treatment basins. Identify suitable locations where future “mud basins” can be constructed.	Minimize the area used for mud containment or treatment. • Find the best compromise between mud containment and soil occupation and use • Minimize loss of valuable agricultural fields. • Ban use of areas with high ecological value (flora, fauna, breeding zone). • Consider less valuable or already degraded soil surface as a priority • Minimize conflict with existing residential/industrial development projects.
		The location of the mud basins should be done in a way that avoids or minimizes the risk of secondary environmental contamination: • Impact on ground water, flora and fauna. • Safe distance between the mud basins and sensitive receptors (marine and aquatic ecosystems). The results of the “risk assessment” (see last section of this matrix) should also be taken into consideration, in particular for dam walls, which are not going to be reinforced.
Sludge or effluent disposal	Since it is almost certain that, at some point, a specified quantity of sludge or effluent	Location of the discharge point should be chosen in ways that minimize the impact on flora and fauna (benthic and pelagic for aquatic and marine

Topics	Goals	Objectives
	generated by the mud treatment should be disposed of in the environment, it is necessary to identify **where, how and when** the sludge can be discharge or disposed in the environment with minimal impact. To achieve this goal, a reliable information system on effluent composition (chemical and physical properties) should be set up.	environment): • Discharge of highly effluent in water in marine coastal ecosystem is devastating whereas discharge in deep water has a much less significant impact. • Breeding area should be avoided • In general, all area of high ecological values or ecosystem sensitive to small modification of their chemical and physical equilibrium should be avoided Timing should also be considered: possible influence of rain season, biological cycles (breading season).
Sludge or effluent disposal (continuation)	The parameters to be analyzed should be identified according to the specific characteristics and sensitivity of the environmental compartments used for mud/sludge disposal.	The longer-term effects of the sludge or effluent disposal should be also assessed and minimized.
Rain water	Assess the impact of the considerable quantity of rainwater that is expected to be collected in the mud basins during the rainy season. Ascertain by testing how the mud will react to this massive input of fresh water: mud dilution or separation in two (or more) phases of different density. Depending on the effluent composition, and expected quantity, it might be necessary to identify a suitable treatment of the prior disposal in the environment.	The same objectives than for the sludge or effluent disposal should be achieved for the excess quantity of rainwater/diluted mud disposal. Regular quality check of the effluent to be disposed in the environment should be carried out.

Topics	Goals	Objectives
Risk assessment	Assess the effect on the population and environment of a possible and significant unwanted and uncontrolled mud or water flow release. Establish credible scenarios of partial dam wall collapse or overflow in the most vulnerable area: proximity of residential area, high value ecosystem, industrial zone. Evaluate the consequences of the uncontrolled and sudden mud or water flow on: • Population (potential number of victims) • Environment (pollution of terrestrial and aquatic ecosystem) • Infrastructures (water distribution and evacuation system, roads and transports, etc.) • Industry (possible source of secondary pollution, loss of properties and production).	Identify the most vulnerable area. • Identify and propose all the requested measures to prevent such event to occur: • Dam wall reinforcement and other special constructive measures (protection of residential and industrial area) • Possible relocation of the most at risk population • Possible redesign or relocation of the mud basin which are found to pose an unacceptable risk • Development and implementation of a safety-monitoring program (dam wall inspection/maintenance, mud basins regular checking, pump check) • Identify and propose all requested measures to minimize and manage the possible consequences of a dam wall collapse or overflow: • Creation of an effective alarm system • Development of contingency planning for population evacuation, relocation and relief • Setting up of a emergency response system and team (including environmental specialists).
	Since the total volume of the mud flow can not be predicted (no accurate estimate of the flow rate and no indication of the duration of the mud release can be made), the possibility to have to dispose untreated mud in the environment should be considered (because of the saturation of the available mud containment capacity).	The same objectives set for the sludge or effluent disposal should be achieved. The possible impact of the “emergency discharge” of a significant quantity of fluid mud in abandoned quarries and in marine environment should be assessed. Based on this assessment, a strategy destined to minimize the impact of a possible “emergency discharge” should be worked out: • Protective measures to be taken • Location of the discharge point • Monitoring procedure.
Rehabilitation and clean up operations	Ensure that the cleaning operations are made in accordance with environmental protection laws and regulations.	Identify the areas that can be cleaned up and recovered as a priority. Provide the public and competent authorities with the necessary information on “environmentally sound” clean up procedures and effluent disposal. Establish a suitable methodology and program for the cleaning up monitoring operations and follow up.

Risk assessment team composition (example)

Specialist	Organization	Responsibility
Civil engineer	ITS	Dam survey and monitoring. Identification of the mot vulnerable dam walls sections. Mud invasion mapping.
Civil Works engineer	Sidoarjo municipality	Identification of the most vulnerable infrastructures : water supply lines, drainage system, energy production and distribution. Contingency planning (water, sanitation and energy).
Town planner	Sidoarjo local Government-Housing Dept. ITS	Identification of the most vulnerable residential, industrial areas. Identification of the most suitable location for short, medium and long term resettlement of displaced persons.
Relief operations specialist	Army/Civil Defense	Preventive and emergency evacuation planning. Creation of a suitable emergency response system.
Security Forces	Police	Road and traffic control during the evacuation operations. Evacuee security. Protection of evacuated residential areas.
Medical doctor	Health sector – local administration WHO	Contingency planning for possible hospital evacuation. Design and organize the medical response system (emergency phase). Prepare medium and longer term medical assistance to the affected populations.

Monitoring and control

Topics	Goals	Objectives
Water, mud and effluent quality control	Determine the relevant existing national regulations or international guidelines/recommendations for: • water discharge in terrestrial and marine ecosystems • effluent and residue disposal.	Establish a list of the quality criteria* and limit values* which will be applied to the water or to the effluents** prior their disposal in the environment. International guidelines and recommendations should be used when the existing national legislation does not indicate parameters/values. **a set of relevant physical and chemical parameters which should be analyzed by accredited laboratories* ***all by-products, sludge, residues produced or resulting from the valorization and mud/water treatment*
	Determine the relevant existing national regulations or international guidelines/recommendations for population and workers health protection.	Depending on the use/valorization of the mud and of the treatment applied to the mud/water/effluents the limit exposure values and the suitable analytical methodology should be identified for: • air quality monitoring during mud/water treatment • detecting possible naturally occurring radioactivity (instable isotopes) or presence of organic/inorganic toxics (especially if the mud is used as construction material such as bricks, building material). These activities should be carried out in close collaboration with the respective concerned authorities such as Ministry of health, Ministry of Energy and Ministry of Labor.
Laboratories and analysis	Identify laboratories able to carry out the requested tests and analysis.	Establish a list of qualified laboratories (preferably accredited laboratories) with fully trained personnel and suitable equipment. Check what are the real capabilities of these laboratories and find out if there is a need for: • more specific training for laboratories technicians and operators • additional equipments.

Action Plan

After a thorough review of the proposed task force organization and activities, the Ministry of Environment team together with the UN expert agree on a series of actions destined to gather the basic information needed to:

- assess the existing scientific and technical resources available
- identify partners organizations
- improve and validate the environmental management task force concept
- identify the need for additional resources (equipment and training)
- provide the details of the structure of each component of the task force.

The list of actions is set out in the matrix below:

Actions	Comments
Make a review of the existing national regulations concerning quality standards for the disposal in the environment of: • water (in river system and marine environment) • solid wastes and residues • effluents.	International guidelines and recommendations should be used when the existing national legislation does not indicate parameters/values.
Based on the review of the existing national regulations and international guidelines, select the relevant parameters which should be analyzed.	The relevant parameters to be considered as a priority are: • usual series of heavy metals • organic components • salinity • suspended solids and turbidity • Cr^{VI} and other ions which can come from secondary pollution (industries).
The same survey should be undertaken for the exposure limit of the worker and population to: • toxic gas (H_2S) • organic compounds • ionizing radiations.	• Possible exposure to toxic gases (mainly H_2S) will mainly concern the workers involved in the mud treatment (modification of the mud Ph might results in gas emission). • Since the “organic smell” is still detectable in the residential area located in the immediate proximity of the mud containment basins, continuous monitoring is required. • Relevant Ministers and Authorities such as Ministry of Health, Ministry of Labor and Ministry of Energy should be consulted and closely associated to this survey.
Establish a list of the accredited laboratories which can be used and visit and interview them to assess the needs for any additional training and equipment.	This assessment should mainly focus on the existing capabilities to carry out: • CG/MS • ion chromatography • atomic absorption • spectrophotometry

Actions	Comments
	• conductivity. It seems that some laboratories already mentioned, lack standard solutions for GC/MS analysis.
Collect relevant maps and geographic information.	The team working on the environmental impact assessment should be provided with the following maps: • hydrogeology and water protection zones • land use (including future industrial and residential development zone) • soil fertility • protected area • bathymetry • zones of particular interest (fish ponds).
Establish environmental assessment teams	A team should be established for each activity listed in the “impact assessment” matrix. Team formation should be discussed and agreed upon with all concerned partners.
Streamline the analysis interpretation and consolidation mechanism	The information should be provided to decision makers under a suitable form. Before being released the analysis results, which consists in a series of data, should be interpreted and consolidated. Therefore, the person in charge of the “Quality control and monitoring coordination” should be able to interpret the analysis in order to ascertain if the water, the mud or any effluent created by the mud treatment pose a risk to the population and the environment. The frequencies of the analysis should also be worked out