Comparison of treatment methods for the assessment of environmental impacts of drilling muds by the LCA approach

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The mud causes considerable pollution impacting several sectors, especially the groundwater system and the staff working on Drilling wells, so as to mitigate the environmental effects of the sludge on the environment we propose two treatment processes (scenarios 1 and scenario 2) like: Thermal desorption, Stabilization/Solidification off line), these treatments are very privileged and used in the field of treatment of oil muds, in (Hassi-Messaoud) Algeria. We use the "life cycle analysis" to evaluate the environmental impacts of each process (the two scenarios), the environmental impacts of each scenario are compared. Which are performed by the use of models of eco-indicator 99 by software “SIMAPRO7”. This evaluation allowed us to identify and quantify the contributions of emissions on human toxicity, the depletion of resources and the ecosystem quality, which are the main categories of impact in this specific Saharian context. The main substances of the assignment of the environment seem to be the chemicals added to the mud. As regards the comparison of the two treatment scenarios, the thermal desorption could be considered as the best method; it has the lowest impact in the three dominant categories scores, aside from the very large consumption of fossil energy causing from atmospheric emission.

Keys words: LCA, environmental impacts, co-indicators, muds drills, potential impacts, environmental impacts, oil drilling mud, environmental impacts assessment, stabilization mud, eco-indicators.

INTRODUCTION

The oil industry is highly developed in Algeria (Hassi Messaoud), however it is known to be generatrice of large quantities harmful wastes for the environment particularly in the petroleum exploration stage these discharges may contain toxic substances such as heavy metals and organic pollutants, and the study was realized in the laboratory of food research (Boumerdes university

The generated drilling waste can reach several thousands of m³ per well, in which there are mainly residual fluids and cuttings.

The storage of drilling waste in the reserve pit can be definitive or temporary before the application of the treatment processes. The potential environmental impacts can occur at several steps of the drilling mud cycle (Ait Amar, 2011), in particular during well drillings when mud is lost and infiltrates groundwater, during storage in the reserve pit and during treatment processes. This is due to the fact that during these steps the emissions (table 1) of hydrocarbons and several toxics products (carbon dioxide sulfur dioxide products of nitrogen and oxygen) will have directly impacts on soils and groundwater.
Scientific assessment of the fate and potential environmental impacts of drilling mud discharged into the Saharan environment can provide the basis for prudent decision making and for minimizing damage to the environment (Goodarznia, et al., 2006). A quantitative methodology for estimating the potential impacts of discharged drilling mud fines should be of use to offshore petroleum operators, regulators, government agencies, and environmentalists (Hauschild M, 2004).

The goal of this study is to analyze and see what the impacts are caused by drilling sludge and the best method for their neutralizing treatment. Then to identify the potential of impacts by impact categories. Facts worth knowing: human health, ecosystem, global warming and the depletion of natural resources for each method of sludge treatment by a Life Cycle Analysis.

MATERIAL AND METHODS

Goal and scope of the study

The goal of this study is to evaluate the environmental impacts of the drilling mud system processing into the country of Hassi Massaoud (Algeria), they use two guardwires process Treatment, blanketing treatment (solidification / stabilization) and thermal treatment which is used after the drilling of wells in the field petrol Hassi Messaoud, and have a considerable pollution potential (figure 1). The (LCA) approach to life cycle is applied to assess the impacts of various waste treatment systems for drilling. The impact assessment is realized on the use of models of LCA (eco-indicator 99 (.Kannan R, 2007) with simapro7 software. This assessment identifies the human toxicity and ecotoxicity terrestrial categories that the main impact in this specific and quantify the contributions of the missions’ arid environment. The impact on the local environment is very important and it is very useful to compare the two sludge treatment scenarios and determine which is the method that has the lowest impact on the environment and see the carcinogetic effects impact. Descriptions of the two treatment methods of drilling muds studied (figure 1)

Both treatment processes of drilling muds compared use two different technologies but perform the same function and they tend to the same goal

General description of drilling mud system

In the oil drilling process (figure 2), sludge is pumped from the mud tank and injected into the well through the drill bit. The mud returns through the well carrying cuttings and emerges back to the surface. The fluids return to the mud pit after separating from cuttings by sifting and centrifuging in mechanical processing of the solids control. During several months, the drilling progresses by phases corresponding to the borehole diameter which decreases more and more with the depth. The first phase (66 cm) is often drilled with water-based mud, whereas the next phases (40.5 cm, 31.0 cm, 21. cm and 15 cm respectively) require the use of oil-based mud. The mud are readjusted
periodically with several additives in order to optimize and improve drilling efficiency. Each phase generates important quantities of drilling waste which is composed of separated cuttings and residual fluids and stored in the reserve pits. Drilling waste can be treated later on by thermal desorption, or solidification/stabilization

**LCA methodology**

Life Cycle Assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle. LCA provides an adequate instrument for environmental decision support. Reliable LCA performance is crucial to achieve a life-cycle economy. The International Organisation for Standardisation (ISO), a world-wide federation of national standards bodies, has standardised this framework within the series ISO 14040 on LCA. The principal phases of the life cycle analysis are represented by the figure 3

1. Goal and Scope Definition, the product(s) or service(s) to be assessed are defined, a functional basis for comparison is chosen and the required level of detail is defined;
2. Inventory Analysis of extractions and emissions, the energy and raw materials used, and emissions to the atmosphere, water and land, are quantified for each process, then combined in the process flow chart and related to the functional basis;
3. Impact Assessment, the effects of the resource use and emissions generated are grouped and quantified into a limited number of impact categories which may then be weighted for importance;
4. Interpretation, the results are reported in the most informative way possible and the need and opportunities to reduce the impact of the product(s) or service(s) on the environment are systematically evaluated.

The assessment of the drilling mud impacts was performed using the impact assessment method life cycle (LCIA) methodology developed in simapro7 software (Pré Consultants, SimaPro, 2007). Many authors have contributed to the development and improvement of these models in various methods as LCA EDIP (Amaryllis Audenaert A,2012); Ecoindicator 99 (Brandes LJ,1996,Dreyer L C,2003); EPS 2000 (Eriksson O,2002) and CML (Wenzel H ,2010) IMPACT 2002+(Finnveden Goran,1999) Human and eco-toxicological impacts are characterized by multimedia models that combine effect information of a toxic substance with its fate modeling. This one is used to calculate steady-state concentrations using the data linked to the physico-chemical properties of the emitted substances and its transport into different
Figure 4. System boundary of thermal desorption (scenario1) and inerting treatment (scenario2)

Environmental compartments. The LCIA models commonly used are CalTOX, USES-LCA, Impact 2002+, and USETox which is a recent model based on scientific consensus for Life Cycle Impact Assessment of chemicals commissioned by the UNEP-SETAC (Ralph K. and Till M., 2008) e main differences between these models are spatial resolution and considered environmental compartments.

The application of this method for the study of the drilling mud impacts constitutes an innovation because this process was mostly applied to the Water, Wastewater and industrial wastes (Goedkoop M, 2000 Guinée J.B, 2001, Jolliet O, 2003, Khodja M, 2008).

LCA is a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system through all stages of its life cycle (Kohler A, 2006).

Life cycle assessment (LCA) and energy analyses of electricity generation systems have been extensively studied worldwide over the past two decades, so (Life Cycle Assessment, LCA, 1998, Malika Ghazia, 2009) the SIMAPRO software uses different methods of impact calculation that can translate the information obtained in the inventory life cycle in impact Environmental. These methods are:

- CML
- Eco-indicator
- Impacts 2002

For the purposes of the study, the method of calculation Eco-indicator 99 Method Eco-indicator 99) was selected because it offers a range of relevant indicators compared to the issues raised by the rudders (Gagnon L, 2002, Renou S, 2006). Furthermore it is recognized by the community scientist and stroke is one of the most commonly used in this area.

**Category of environmental impacts**

Eco Indicator 99 is the first method which established relatively coherent damages in resources, human health and quality of ecosystems. This makes it one of the interesting methods to apply. The values of the coefficients and detailed description of the method can be found on the internet (www.pre.nl).

The methodology écoIndicateur 99 was developed from the top down (top down), starting damage (human health, ecosystem quality and mineral and fossil resources) to identify the impact generating most significant impacts and connect the emission inventory. The method chosen is the Eco-indicator 99 method, this method is one of more consensus in the world of stroke. The calculation methods used to translate flow of materials and energy impact environmental (Rosenbaum RK, 2008, Ryding SO, 1991)

List of indicators included in the eco-indicator 99 method: Carcinogens, Breathing organics, breathing inorganic, Climate change, Radiation, Ozone Layer, Ecotoxicity, Acidification / Eutrophization, Land use, minerals (Suh YJ, ad Rousseaux P, 2002)

**Descriptions of the two treatment methods of drilling mud studied**

The treatment processes of drilling mud compared use two different technologies but perform the same function and they tend to the same goal. Two scenarios are presented in the figure 4, for the two treatment methods with the system boundary which is
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**Scenario 1:**

Mud is temporarily stored in the reserve pit, and later taken for treatment by stabilization / solidification offline. At the end of this treatment, the cuttings are solidified, and discharged into the ground. The transport process is related to movement of vehicles and Machines.

**Scenario 2:**

The sludge is temporarily stored in the reserve tank, and thereafter transported to the thermal desorption unit (thermal phase separation, the cuttings are indirectly heated to remove volatile and semi-volatile components in soil incinerating. At the end of this treatment, the cuttings were below 1% in oil, and transportation will be neglected.

**RESULTS**

Inventaire Lifecycle is the acquisition of all the input and output data system. Data are related to the selected functional unit. The data sources are calculated from the database SIMAPRO 7, measured from the quality of the drilling mud in reserve pits and collected from bibliographical references.

Table 1 shows the average concentrations of inflows for both treatment methods, and the volume of drilling...
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Figure 6. Normalization of the environmental impacts (study of damage) of “scénario1 and Scenario2” by the éco-indicator 99 method

Figure 6 bis. Normalization of the environmental impacts (study of damage) of “scenario 1 and Scenario2” by the éco-indicator 99 method

waste stored in reserve chute. These averages were calculated flows from the location of sludge treatment data and taken as reference values.

The environmental impacts of the two treatments scenarios of drilling mud were studied separately and compared to analyse their environmental advantages and define improvements. Figures 5 to 7 bis, shows the contribution of the different processes in each scenario.

RESULTS AND DISCUSSION

Comparison of impacts by characterization of environmental impacts by the Eco-Indicator 99 processing drilling mud method for both scenarios (characterization).

The characterization phase (figure 5 and 5 bis) allows converting the results of the inventory in a common unit according of their respective contributions to the impact category considered.

This step aims to characterize the inputs and outputs a function of their contribution degree to impact. This leads to convert all the components involved in an impact by a common measure to show a numerical indicator.

For “scenario 1” treatment with inerting can be noted that the sludge and cement obtained are responsible for all impacts therefore drilling mud are composed of organic and inorganic chemicals, which are hazardous to the human health because of the odor from the cuttings and impacts of organic and inorganic respiratory effects when diesel consumed by this process cause depletion of natural resources and sources may be carcinogenic and climate change following organic volatile compounds issued by “Scenario1”

Comparison of impacts by normalization of environmental impacts by the Eco-Indicator 99 processing drilling mud method for both scenarios (weighting).

The normalization phase can quantify the relative importance of different impacts (figure 6 and 6 bis) between them. It is therefore controversially as it is weighted and then add the impact of different types, requiring high taken-party sometimes considered arbitrarily.
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Although this step is the one that brings the most understandable result for the general public as a result in a single value, it is optional because it is one of the most subjective.

It is clear that the incineration of drilling mud by the thermal desorption method (scenario 2) causes a very strong odor clearance which causes a considerable increase in potential impacts for organic respiratory effects (83%) and inorganic (20%). Environmental impact on eutrophication potential is of the order of 95% in the treatment by solidification / stabilization due to the composition of cutting that contains substances responsible to this impact category as phosphorus. To impact the carcinogenic aspect, each flow has its impact (0-50%). Contrary to the treatment method by thermal desorption which has an impact of eutrophication 10% caused by the incineration of drilling mud with a high temperature that will remove substances potential greenhouse caused by the release of volatile organic components (VOCs) that has effect on climate change and the potential impact of the sludge to 30% and 90% for the cement.
Table 2. The matrix of some emissions and extractions calculated by simapro for the two scenarios

<table>
<thead>
<tr>
<th>Emitted parameters</th>
<th>Unit</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Kg</td>
<td>+0.523E-03</td>
<td>-1.1E+03</td>
</tr>
<tr>
<td>Electricity</td>
<td>KJ</td>
<td>-1.2E+03</td>
<td>-2.1E+03</td>
</tr>
<tr>
<td>Barite</td>
<td>Kg</td>
<td>4.5E+03</td>
<td>5.2E+03</td>
</tr>
<tr>
<td>Bentonite</td>
<td>Kg</td>
<td>3.2E+02</td>
<td>3.3E+01</td>
</tr>
<tr>
<td>Carbon</td>
<td>Kg</td>
<td>9.2E+05</td>
<td>-2.2E+05</td>
</tr>
<tr>
<td>Natural gas</td>
<td>m3</td>
<td>-3.3E+03</td>
<td>-3.3E+03</td>
</tr>
<tr>
<td>Iron</td>
<td>Kg</td>
<td>8.1E+02</td>
<td>1.8E+02</td>
</tr>
<tr>
<td>Air emissions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>Kg</td>
<td>3.6E+08</td>
<td>-2.7E+06</td>
</tr>
<tr>
<td>CO</td>
<td>Kg</td>
<td>4.4E+03</td>
<td>-6.4E+01</td>
</tr>
<tr>
<td>NOx</td>
<td>Kg</td>
<td>7.4E+01</td>
<td>-2.5E+05</td>
</tr>
<tr>
<td>VOC</td>
<td></td>
<td>1.5E+04</td>
<td>1.2E+05</td>
</tr>
<tr>
<td>Soil emissions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>Kg</td>
<td>7.8E+02</td>
<td>1.4E+09</td>
</tr>
<tr>
<td>As</td>
<td>Kg</td>
<td>3.7E+05</td>
<td>1.6E+05</td>
</tr>
<tr>
<td>Cr</td>
<td>Kg</td>
<td>2.7E+03</td>
<td>1.6E+03</td>
</tr>
<tr>
<td>Pb</td>
<td>Kg</td>
<td>1.0E+09</td>
<td>1.2E+02</td>
</tr>
<tr>
<td>Cu</td>
<td>Kg</td>
<td>3.6E+02</td>
<td>5.6E+04</td>
</tr>
<tr>
<td>Zn</td>
<td>Kg</td>
<td>5.2E+02</td>
<td>1.9E+03</td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>Kg</td>
<td>6.2E+08</td>
<td>1.5E+04</td>
</tr>
</tbody>
</table>

Comparison of impacts by weighting of environmental impacts by the Eco-Indicator processing drilling mud method for both scenarios, category (study of damage)

. The Weighting (figure 7 and 7 bis) phase provides a unique environmental note for the product analyzed. The weighting therefore needs to give more weight to impacts that are considered more “serious”. It is therefore controversially as it is weighted and then add the impact of different types, requiring high taken-party sometimes considered arbitrarily. Although this step is the one that brings the most understandable result for the general public as a result in a single value, it is optional because it is one of the most subjective

In more detail, we see that In human health, 45% (S1) and 30% (S2) potential impacts are attributable to the drilling mud and mainly its chemical composition (bentonite and polymers); while for the (S1) fuel consumption reached 70% compared to the impact (S2) is very low, if not negligible finally Portland cement intervenes mainly for the (S1)

For this category, the indicator Ecosystem quality is mainly influenced by the final destination of the sludge "S1" more less 75% before the thermal system with the sludge has no influence, also the impact of diesel is very striking, (90%) of the energetic operations "S2" compared to 25% of the "S1" For resources use, it is almost only the extraction of non-renewable raw material is at stake, with 100% impact resulting from the use of fossil fuels and 80% utilization of rocky material.

The Table 2 gives for each treatment scenario the matrix of some emissions and extractions calculated by SIMAPRO. The negative values in scenarios 1 and 2 correspond to emissions and extractions avoided by recovering oil during vertical centrifugation and thermal desorption.

CONCLUSION

One of the major results Obtained by the Life cycle analysis of drilling mud system as possible to underline the stages That present the major impact and compare the environmental impacts of the two scenarios Studied, because in the absence of norms or clear environmental guidelines, in the field of the recovery and regeneration of drilling muds allow decision makers a tool for to properly deciding

Since the main rule of environmental protection is to remove all harmful pollution on the environment and human health without generating another pollution, the analysis results of the life cycle for both methods of treatment; shows that thermal desorption has less impact on the ecosystem, human health and depletion of natural resources. This treatment is based on the incineration of waste drilling that uses only the fuel (diesel), although the quantity of the latter is three times more than that consumed by the processing method inert. For the first scenario against treatment (inerting) uses several natural materials and other products used in the treatment (cement, sand and sodium silicate). They have, among other significant impacts on the ecosystem and human health and even global warming With regard to a comparison of the treatment scenarios it appears that the stabilization / solidification line is the best; it has the lowest score of the impact in the two categories as a result of waste reduction: Storage mud avoided in reserve tank. The second best scenario is thermal desorption who gets the lowest score of the impact of carcinogenic effects as a result of the reduction of hydrocarbons (<1%) and avoided impacts of recovered oil. The modeling of toxic substances out will be improved by considering their particular impact site.

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