

Case Study: Biological Treatment of Geothermal Drilling Cuttings

Frydda Sandoval¹, J.B. Randle²

Polaris Energy Nicaragua S.A., Ofiplaza El Retiro #723, Rotonda El Periodista, 150 m al sur, Managua, Nicaragua

¹fsandoval@polarisgeothermal.com, ²jrandle@polarisgeothermal.com

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ABSTRACT

This paper focuses on the bioremediation technology used for the mud and the drilling cuttings obtained during the drilling of five geothermal wells in the period between August 2007 and May 2008. Polaris Energy Nicaragua S.A. is developing the San Jacinto Tizate geothermal project near to Leon, Nicaragua. The first well drilled reached a depth of 150 meters, but was abandoned after a blowout at 150 m. The other four (reinjection and production) wells were drilled successfully without problems and reached depths of between 1000 and 2000 meters.

The geothermal well drilling process may negatively impact the environment, therefore it is necessary to introduce measures in order to prevent, control and mitigate the environmental impacts that they can produce. The mud and the drilling cuttings are a key environmental issue after the process of drilling a well. The biological treatment, also known as biotreatment or bioremediation, uses microorganisms like: bacteria and fungi to biologically degrade waste into nontoxic residues. The objective of biotreatment is to accelerate the natural decomposition

process by adding: manures that contribute to the fertility of the waste, nutrients, aeration, moisture, and a small portion of soil.

Some advantages of biological treatment are: it is relatively environmentally benign; it generates few emissions; wastes are converted into useful products; and it requires minimal transportation. In this case bioremediation was used as a final disposal step and the waste was used for establishment and growth of vetiver grass for use elsewhere in the project as erosion control planting.

1. INTRODUCTION

Polaris Energy Nicaragua S.A. is developing the San Jacinto Tizate geothermal project in the Telica municipality, departament of León. The company drilled five geothermal wells in the August 2007 – May 2008 period. This paper shows the treatment technique employed to treat solid residues obtained during drilling. The liquid (water) component of the drilling mud was re-injected into drilled wells; the process described here refers to: the separation of the liquid and solid phase at the source of generation, transfer of the mud, final treatment.

The following figure shows the drilling mud management scheme used in the site.

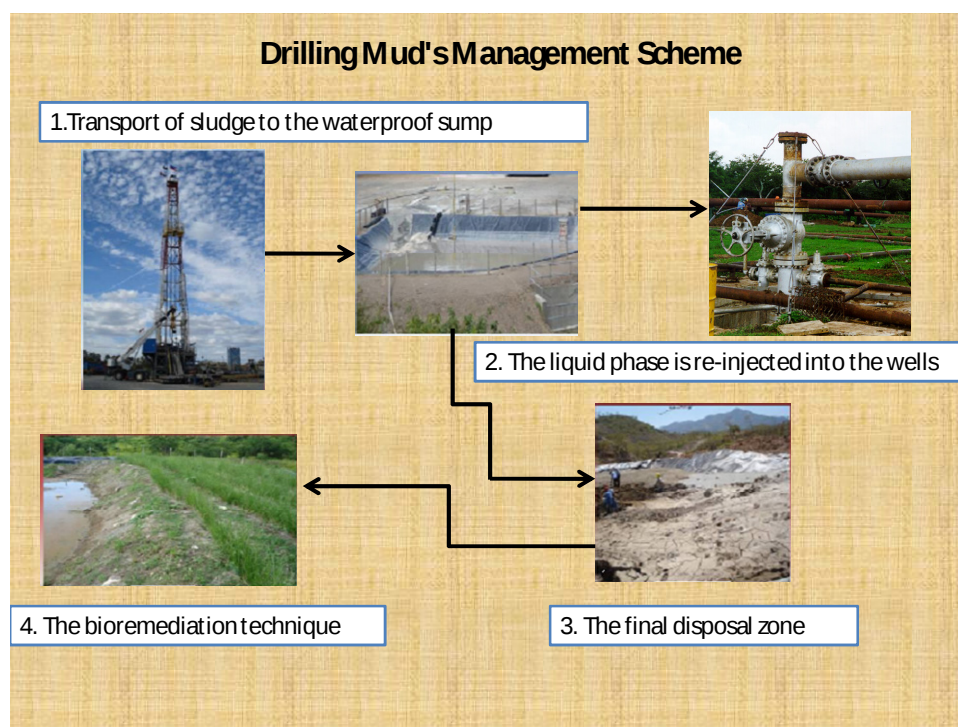


Figure 1: The figure above shows the drilling mud management scheme used on site during and after the drilling process

2. SOLID EFFLUENTS MANagements

Only water-based fluid is used in the project at each of the drilling stages. However, due to the nature of the drilling cuttings, these require special handling to diminish adverse impacts to the environment.

Drilling cuttings are small rock fragments (clay, sands, lutites, etc.) that are generated due to the cutting and grinding action of the drill bit. These cuttings are transported to the surface by means of the drilling mud, which is impregnated in their surface area. Due to this impregnation, the degree of contamination will depend on the nature of the drilling fluid and the characteristics of the drilled zone. Drilling cuttings management practices referenced in this paper are "Louisiana Statewide Order 29-B Regulation 29B of Louisiana, USA".

2.1 Mud Volume

Based on the design of the wells we had a total of 844.63 m³ of drilling mud to treat. The estimate volume of drilling cuttings from one well, SJ6-2, is shown by way of an example in the table below.

Table 2. Estimated Volume of Drilling Cuttings from SJ6-2 Well.

Well SJ6-2						
Directional Well. Large Diameter. Depth 2,000 meters						
Diameter (Inches)	From to (Meters)	Depth (Meters)	Theoretical Volume (m ³)	Expansion Factor	Return to surface	Expected Volume (m ³)
32	0 – 39	39	20.23	2	100.00%	40.46
24	39 – 159.5	120.5	35.16	2	100.00%	70.31
17.5	159.5 – 600.5	441	68.41	2	100.00%	136.81
12.25	600.5 – 1473	872.5	66.32	2	35.00%	46.42
8.75	1473 – 2000	527	20.44	2	0.00%	0.00
Total						294.00

The theoretical expansion factor taken refers to the capacity of minerals to absorb water and expand; their volume is greater than the theoretical but not all minerals have that property. The return to surface refers to the mud losses that take place in geological fractures; note that there is no longer total return of mud in the target zone of the well.

2.2 Collection System

A gabion filter was built on the project's drill pads at the exit of the mud discharge system (metal trays called "shakers" ["temblorinas"]), with the purpose of separating the liquid or aqueous phase from the solid phase. The solids that have been collected in the gabion filter, are mixed with lime to accelerate the drying process. A backhoe is then used to load the solids onto a dump truck, which takes them to the final disposal zone. The dump truck has a built-in lid to avoid any type of spill.

The liquid phase is sent to the platform's mud sump. Once the well's target zone is found (losses are encountered), this liquid phase is injected into the well, and thereafter drilling is done with water, not mud.

3. TREATMENT

Land-farming is a bio-remediation technique that is used to decontaminate "in situ" as well as "ex situ", and consists of provoking biological oxidation of contaminating agents contained in the soil, by means of stimulating natural microorganisms found in the soil (yeasts, fungi or bacteria) by the addition of fertilizers, aeration and surface irrigation.

This is a bio-stimulation of the necessary populations we are interested in activating. The land-farming process has a series of advantages that are: low cost, does not leave residues, does not cause (if performed in controlled conditions) contamination risks.

The effectiveness of this methodology depends on countless factors such as contaminant type and concentration, nutrients, aeration, environmental conditions, presence of inhibitors, concentration of microorganisms, etc. (EPA, 2001; Ercolli et al., 2001, Marín et al., 2006). The capacity to control and optimize all these variables mentioned above is what will determine the efficiency of the land-farming process.

3.1 Mix Procedure

Two basins were prepared to receive the drilling mud. The first one, the one with the smaller volume, already existed and only required the addition of a geo-membrane: the second basin, with a greater volume, was built before discharging the material. The treatment process was carried out in two phases that consist of the disposal of the mud in the small basin until it reached its volume and then in the relocation of these into the second basin.

At this stage, work was only the first phase of the biological treatment. Mixing the mud with the materials that intervene in the bioremediation technique.

In this manner, the mud discharged in this larger basin was mixed in proportional percentages with fresh manure, plus soil and Triple 15 fertilizer, in approximate proportions of ten full shovels of mud with 5 full shovels of manure and another 5 full shovels of soil plus fertilizer. In other occasions, the bucket of a backhoe was used and the ratio was, in that case, one bucketful of mud plus another one of soil and manure, plus fertilizer.

The mud mix, along with the other components was aerated by overturning and was irrigated for several weeks. After two months of overturning, plots were established for sowing vetiver (rustic tropical grass, originally from India but broadly used in Asia and Africa for building live hedges to control erosion, apart from being used for fodder for beasts of burden and construction material). Fito-remediation technique: Vetiver has not been reported as accumulating contaminants, nonetheless it has been adapted to the mud mix. Also, even though it does not accumulate contaminants, it may count with positive aspects in its rhizosphere that contribute to the elimination of toxic elements.

Likewise, with the establishment of Vetiver plots, we were able to establish a reserve bank of this plant to be used in other vulnerable areas around the project that require erosion control.

The bioremediation technique was chosen for the treatment of the drilling mud because this is a suitable technique to be used in processes for the degradation of organic contaminants in the soil, existing microbial populations are increased and, at the same time, the activity of autochthonous microbial populations will be stimulated, the concentration of enzymes in the media will be increased, which will help to maintain the humidity and improve the characteristics of the same.

4. RESULTS

Up to date, two heavy metals analyses have been performed on the materials; the first one was performed in February

2008. The goal of this was to establish a baseline to determine the initial concentrations in the mix before being treated with the bioremediation technique. The second round of analyses was performed in June 2008, four months after the treatment had begun.

Concentration limits for these types of residues have been compared with Order 29-B, which is applicable for all oil filed pools, including unlined earth pools (reservoirs) employed for drilling operations throughout the State of Louisiana, United States.

Table 2. Limits for Waste Confinement According with Order 29-B, State of Louisiana, USA.

Parameter	Maximum concentration
PH	6 – 9
Electric conductivity (mmhos/cm)	<12
Sodium Adsorption Ratio (SAR)	NA
Oils and Greases (% per weight)	<3 %
Arsenic	10 mg/Kg.
Barium	40,000 mg/Kg.
Cadmium	10 mg/Kg.
Mercury	10 mg/Kg.
Selenium	10 mg/Kg.
Silver	200 mg/Kg.
Chromium	500 mg/kg.
Zinc	500 mg/kg.
Lead	500 mg/kg.

The first results of the monitoring are shown in the next table.

Table 3. Report of Analysis from Laboratorios Químicos S.A. LAQUISA.

Analysis	UM	N0.1 Pad G	N0.2 Pad J	N0.3 Taken from the mud drying on the ground
pH	---	9.3	7.9	7.6
Electric conductivity	Ks/cm	2.6	4.99	7.4
Sodium (Na)	%	0.25	0.26	0.35
Mercury (Hg)	µg/g	524.7	59.5	7.9
Lead (Pb)	mg/kg	2.6	22	1.7
Arsenic (As)	mg/kg	0.72	0.71	0.72
Copper (Cu)	mg/kg	131.5	132.3	164.7
Barium (Ba)	mg/kg	<0.2	<0.2	<0.2
Chromium (Cr)	mg/kg	<0.06	<0.06	<0.06
Zinc (Zn)	mg/kg	82.2	82.7	82.3
Silver (Ag)	mg/kg	<0.02	<0.02	<0.02
Sulfate (SO ₄)	%	0.95	0.17	0.49
Manganese (Mn)	mg/kg	871.2	1405.02	428.1
Iron (Fe)	%	2.56	2.41	2.61
Greases and oils	mg/kg	462.1	1680.0	270.00

When comparing these values with the table for confining limits in Louisiana, it can be seen that the highest concentrations in ppm correspond to the values for Manganese, Mercury and Copper.

Table 4. Analytical results of heavy metals in drilling mud samples. Center for Research on Water Resources in Nicaragua. CIRA, Managua.

Parameters	µg/g ¹	N0.1 Small basin untreated mud	N0.2 Small basin untreated mud	N0.3 Large basin untreated mud	N0.4 Large basin mud with manure	N0.5 Large basin mud vetiver plot	N0.6 Large basin mud vetiver
Total Arsenic	µg/g	1,1750	1,290	2,080	1,900	1,620	2,280
Total Cadmium	µg/g	1,429	0,798	0,532	0466	0,428	<ld
Total Copper	µg/g	109,011	94,97	109,550	106,260	102,980	103,540
Total Mercury	µg/g	<ld	<ld	0,052	0,108	0,306	0,184
Total Lead	µg/g	4,324	<ld	3,312	5,253	<ld	<ld
Total Selenium	µg/g	8,158	0,068	<ld	<ld	<ld	<ld

Total copper samples in all sampled sites show a high concentration, behavior pattern that appeared in the first analysis performed previously.

Lead displays a different behavior, the concentration of sample No.4 is the highest one compared to the sample of point No.1 and No.3.

Total selenium concentration in sample No.1 is the only one that can be detected by the analysis because in the following samples its concentration was below the detection limit.

Unlike the previous sampling, total mercury limits are below the detection limit and hence lower than the permitted limit.

CONCLUSION

The drill cuttings management program implemented at the San Jacinto Tizate Geothermal project has treated approximately 845 m³ of solid drilling residues.

The bio-recovery technique has allowed us to take advantage of the potential of this residue, that is to say the recovery of its soil properties. The residue would alternatively have had to have been subject to an expensive confinement or encapsulation treatment, with long term monitoring implications.

However, treatment systems with live organisms help us to better understand the way nature works where the byproduct of an activity represents the source of energy for other processes.

REFERENCES

- Ercoli, E. et al. Biorremediación de “suelos” por técnica de *acumulación aireada*. IV Jornadas de Preservación de Agua, Aire y Suelo en la Industria del Petróleo y del Gas. IAPG. Salta Argentina (2000).
- Tettamanti, G., Svaboda, A. y Ercoli. Experiencia de biorremediación de suelos por técnicas biológicas en la provincia de Santa Cruz. UNAS, Repsol YPF, Argentina. Universidad Nacional de Cuyo, Mendoza, Argentina.
- Frydda Sandoval. Programa de manejo de los lodos de perforación. Polaris Energy Nicaragua S.A., Septiembre del 2008.
- Ricardo C. Pasquali. Química Ambiental. Serie ingeniería. 2008.
- Louisiana Statewide Order 29-B, USA