American Journal of Environmental Protection, 2018, Vol. 6, No. 4, 98-102
Available online at http://pubs.sciepub.com/env/6/4/1

DOI:10.12691/env-6-4-1

Treatment of Petroleum Drill Cuttings by Water-Based Drill Cuttings Plant Using Solidification/Stabilization Treatment Method

John Leju Celestino Ladu*, Paul L. Demetry, Andrew L. Athiba, Stanislaus T. Venusto Lako

College of Natural Resources and Environmental Studies, Department of Environmental Studies,
University of Juba, P.O Box 82, Juba, Republic of South Sudan
*Corresponding author: johnleju@yahoo.com

Received October 01, 2018; Revised November 20, 2018; Accepted December 18, 2018

Abstract High concentrations of heavy metal and oil & grease contents in petroleum drill cuttings are a substantial obstacle which affects treatments and consequently reduces the clean-up efficiency of the stabilization/solidification (S/S) process. In this study, a Water-Based Drill Cuttings Plant was used for the treatment of drill cuttings wastes. The main purpose of this study is to assess the efficiency of the water-based drill cuttings plant using S/S treatment Method. Samples of treated wastewater effluent and soils before and after subjected to the drill cuttings treatment plant on site were collected. A range of parameters were analysed from the sampled wastewater and soils. The trace elements and heavy metals such as; copper (Cu), Zinc (Zn), Iron (Fe), Manganese (Mn), Chromium (Cr), Cobalt (Co), Nickle (Ni), Lead (Pb) and Cadmium (Cd) were within the normal expected ranges for both samples from the ponds containing treated and untreated drill cuttings. The routine soil parameters of pH, organic matter (OM), Nitrogen (N), Potassium (K), Sodium (Na), Calcium (ca) and magnesium (Mg) from pond before and after treatment were not statistically significant. It suffices to note that the soil samples from the pond containing wastewater before treatment (the drill cuttings pond) had significantly high levels of oil & grease. This could be attributed to the oil & grease levels leaching from the contained wastewater to the soil before its treatment. The results generally show that a number of wastewater effluent and soil parameters from the water-based drill cuttings plant complies with both the Sudanese Guidelines for discharge and the Ugandan effluent discharge standards (NEMA) except for Total iron, Cadmium, Chromium, and Oil & grease, hence a reflection of the adequacy of the treatment plant.

Keywords: *water-base drill cuttings, stabilization/solidification, heavy metal, oil & grease, leaching*

Cite This Article: John Leju Celestino Ladu, Paul L. Demetry, Andrew L. Athiba, and Stanislaus T. Venusto Lako, “Treatment of Petroleum Drill Cuttings by Water-Based Drill Cuttings Plant Using Solidification/Stabilization Treatment Method.” *American Journal of Environmental Protection*, vol. 6, no. 4 (2018): 98-102. doi: 10.12691/env-6-4-1.

1. Introduction

Human population growth, technological advancement has lead to over-exploitation of natural resources which in turn has resulted into depletion of valuable natural resources and severe environmental pollution. In the last few years, natural self-purification mechanisms of the environment have not been sufficient enough to cope with contaminations calamities, especially in developing countries. Non renewable resources such as fossil fuels (specifically oil) are the main major resources of energy for industries. During oil exploration and extraction, a massive volume of wastes or drill cuttings are generated [1]. According to a survey performed by the American Petroleum Institute (API) in 1995, the accumulated volume of wastes generated from crude oil and natural gas exploration and production was estimated to be approximately 140 million barrels [2]. Different methods and techniques are employed to manage drill cuttings. One of the best known techniques to manage the risks of hazardous waste (drill cuttings) is the stabilization/solidification (S/S) process [3], which is usually carried out prior to the conduction of other treatments methods. This approach has been in used since the early 1970s [4]. The Environmental Protection Agency (EPA) endorses S/S as a method by which the physical and chemical characteristics of waste and its handling are improved and the mobility, solubility, and toxicity of contaminants are mitigated [5]. The EPA has also reported that the S/S method was used in the treatment of 22% of Superfund sites from 1982 through 2005 [6]. Lack of related studies and high volume of such wastes necessitated an experimental research to investigate the feasibility of S/S process and results.

In addition, this method has been identified by the EPA as the best demonstrated available technology (BDAT) to clean up 57 types of Resource Conservation and Recovery Act (RCRA) listed hazardous waste [7]. The technique has also been employed to remediate soil contaminated with heavy metals and to immobilize organic pollutants in soil, sediment and waste [8,9].

Stabilization/ solidification (S/S) involves the use of various inorganic binders, including cement, lime, clay, fly ash, silica fume, and other pozzolanic materials [10]. The method may also use organic materials such as bitumen products, epoxy, and resins [11]. It was reported that 94% of Superfund sites were treated using inorganic binders [6].

Advantage of Solidification treatment (Onsite advantage) is that, it protects human health and the environment by immobilizing hazardous constituents within treated material, final disposal alterative related to best environmental practices, can be completed in a relatively short time period and the process equipment occupies relatively small footprint.

Historically, cement, fly ash, lime and calcium oxide have been used most frequent as solidification/stabilization additives for treating drill cuttings and other types of wet solids. Not all drilling wastes are amenable to chemical fixation and stabilization treatments. Solidification/stabilization should be adapted for site-specific applications depending on the end-use of the treated material and the chemical characteristics of the waste. Conducting laboratory tests to determine the proper blend of additives to achieve the desired materials properties is recommended. Some companies have used solidification/stabilization for drilling wastes. The resulting materials have been used for road foundations, backfill for earthworks and as building materials [12] and may be used for other purposes [13]. Most of the solidification/stabilization systems produce conditions both of high pH and high total alkalinity. Much concern is the failure of the additives to keep the waste constituents from releasing into the environment of the long term of the sudden release of the contaminants due to breakdown of the matrix. A solidified waste is an amorphous solid at least partially saturated with water. It consists of one or more solid phases, entrapped air in the form of air voids and a liquid phase; all are in the chemical equilibrium or close to it. When the solid is exposed to leaching conditions, equilibrium is disturbed. The leaching mechanisms assume that no chemical reactions occur (other than those involved in the dissolution of the constituents in the solid). While this might be true in laboratory leaching tests, it is not the case in the real environment. Rain, surface water and groundwater all contain constituents that may increase or decrease the leaching rate (e.g., redox potential, pH, anions such as carbonate, sulphide and silicate, organic chelating agents and adsorptive particulates).

There are limitations on the applicability of stabilization/ solidification systems. For example, cement-based systems do not work when: the organic content is above 45% by weight, the wastes have less than 15% solids, excessive quantities of fine solid particles are present, and too many large particles are present. As noted, the most commonly used additive materials have a high pH, which can pose a problem if the stabilized wastes are subsequent land-applied or used as a soil supplement. In a series of studies to test the suitability of using treated cuttings to grow wetlands vegetation, researchers at Southeast Louisiana University discovered that cuttings stabilized in a silica matrix had a pH value higher than 11. The stabilized cuttings did not support plant growth as well as un stabilized cuttings [14].

The major purpose of this study is to assess the efficiency of the Water-Based Drill Cuttings Plant Using Solidification/Stabilization treatment Method in order to know whether the treated effluent can be safely discharged into the receiving environment and other uses or not.

2. Materials and Methods

2.1. Characterization of the Waste

The wastewater used in this study was obtained from the drill mud pit in Moleeta oil field under the operational sites of Dar Petroleum Operating Company (DPOC), extracted from a depth of 400 cm, well No. MoL 21 in Upper Nile State, Republic of South Sudan.

2.2. Experimental Setup

A Water-Based Drill Cuttings Plant (Figure 1) was established in Moleeta (MoL 21) for the purpose of treating the drill cuttings before discharge to the dug pit and other uses. The influent for the treatment plant was collected from the drilled mud pit in Moleeta (MoL 21)-in Moleeta oil field and then pumped into a storage tank as influent to the system (Solidification/Stabilization treatment system). The drilling fluid was oil-based.

Figure 1. Photo of Water-Based Drill Cuttings Plant on site in MoL 21

2.3. Wastewater and Soil Sampling

Samples of treated wastewater effluent from the drill cuttings treatment plant on site were collected from the pond where it collects after treatment (Figure. 2). The type of wastewater used for this study was characterized by high-strength wastewater fluctuating in its concentration of pollutants. The main objective of sampling was to collect a portion of materials small enough in volume to be transported conveniently and yet large enough for analytical purposes while still accurately representing the material being sampled. This implies that the relative proportions or concentrations of all pertinent components will be the same in the samples as in the material being sampled, and that the sample will be handled in such a way that no significant changes in composition occur before the tests are made.

Five grab samples were collected from different locations of the drill cuttings treatment plant on site by filling the sampled treated wastewater in a glass bottle and these were combined to form one composite sample. Onsite tests of pH, temperature, total dissolved solids and conductivity were made on the composite sample. About 1.5 litre sample was put in a clean container and carefully transported (within one day) to Public Health and Environmental Engineering laboratory (Makerere University, Uganda) for analysis.

Figure 2. Pond where the discharged effluent are contained after treatment by the plant

Additionally, two composite soil samples from the drill cuttings pond were collected, one from the containment pond before treatment (drill cuttings pond) and the second one from the pond containing the treated effluent of the drill cuttings. Five grab samples were picked from different locations and mixed to form composite samples. About 500g of the composite samples were carefully packed and transported to Soil science laboratory (Makerere University, Uganda) for subsequent analysis.

2.4. Laboratory Analysis

While at the laboratory, the wastewater effluent sample was tested for parameters of apparent colour, sodium, aluminium, chlorides, nitrates, potassium, sulphates, total phosphorus, carbonate, total iron, cadmium, calcium, chromium, zinc, barium, copper, ammonium and oil & grease. Conductivity, pH, TDS and temperature were measured in-situ using a portable meter. The rest of the above stated parameters were determined in the laboratory according to standard methods for examination of water and wastewater [15].

On the other hand, soil samples from the drill cuttings pond were tested for parameters of texture (% sand, silt and clay), pH, organic matter (OM), nitrogen (N), available phosphorus (Av. P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), oil and grease (O & G), copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), chromium (Cr), cobalt (Co), nickel (Ni), lead (Pb) and cadmium (Cd). Soil samples were prepared before analysis by air-drying, crushing and passing through a 2-mm sieve to remove any debris (extraneous materials). Samples were then subjected to physical-chemical analysis following standard methods described by [16]. Soil pH was measured in a soil water solution ratio of 1: 2.5; Organic matter by potassium dichromate wet acid oxidation method; total N determined by Kjeldhal digestion; Extractable P by Bray P1 method; exchangeable bases from an ammonium acetate extract by flame photometry (K+, Na+) and atomic absorption spectrophotometer (Ca^{2+}, Mg^{2+}). Soil classification in terms of texture (% silt, sand and clay) was determined using the hydrometer analysis method. Parameters of heavy metals and trace elements were extracted using EDTA and measured by atomic absorption spectrophotometer (AAS).

2.5. Treatment Adequacy

For the case of soils, the soil properties obtained from the drill cuttings pond containing wastewater before and after treatment were compared to assess the impact of the contaminants in the soils. The adequacy of wastewater treatment was gauged by examining the concentrations of parameters in wastewater against acceptable discharge standards for the treated effluents. Here, the Sudanese Guidelines for discharge were used in comparing the contaminant concentrations in wastewater effluents. In case of absence of discharge guidelines values in the guidelines, the values in the National Environment Management Authority (NEMA) discharge standards, Uganda were adopted. If the treatment is adequate, the effluent sampled wastewater was expected to comply with both Sudanese guidelines for discharge and NEMA effluent discharge standards. Table 1 shows the extract of the standard effluent guideline values from the NEMA standards for the measured wastewater quality parameters. In addition, the detection limit for each of the measured parameter is also indicated.

Table 1. NEMA effluent discharge guidelines for wastewater sources

Parameter	Unit	NEMA effluent standards*	Sudanese Guidelines for Discharge	Detection limit
pH		**6.0-8.0**	6.0-9.0	
EC	µS/cm	**ns**		
TDS	mg/L	**1200**		
Temperature	°C	**ns**		
Apparent colour	Pt Co.	**ns**		
Chlorides	mg/L	**500**		
Nitrates	mg/L	**20**	30	
Sulphate	mg/L	**500**		
Carbonate	mg/L	**ns**		
Total phosphorus	mg/L	**10**		0.004
Potassium	mg/L	**50**		
Sodium	mg/L	**1250**		
Total Iron	mg/L	**10**	1	0.001
Calcium	mg/L	**100**		
Cadmium	mg/L	**0.1**	0.01	0.001
Chromium	mg/L	**1.0**	0.05	0.001
Copper	mg/L	**1.0**	1.5	0.001
Zinc	mg/L	**5.0**	1	0.001
Cyanide	mg/L	**0.1**		0.01
Aluminium	mg/L	**0.5**	25	0.001
Barium	mg/L		2	
Oil and grease	mg/L	**10**		0.1

Notes: ns-* Uganda National Effluent discharge standards. Ns-not specified.

3. Results and Discussion

3.1. Soil Classification

Soil results for the area, considering both the samples taken from pit/pond containing untreated and treated wastewater show that it is predominantly clay (Table 2). Soils with high clay content exhibit high cation exchange capacity (CEC) due to the very high surface area. Additionally, clay soils are characterised by very low permeability and such property limits the leaching of the contaminants in case of any chemical spill.

Table 2. Soil classification of the area

Sample No.	% Sand	% Clay	% Silt	Classification
A	30.0	21.0	49.0	Clay
B	51.0	28.0	21.0	Clay

Notes: A-Soil where untreated wastewater is collected; B-Soil where treated wastewater collects.

3.2. Soil Trace Elements and Heavy Metals

The trace elements and heavy metals such as; copper (Cu), Zinc (Zn), Iron (Fe), Manganese (Mn), Chromium (Cr), Cobalt (Co), Nickle (Ni), Lead (Pb) and Cadmium (Cd) were within normal expected ranges for both samples from the ponds containing treated and untreated drill cuttings (Table 3). However, the minimal variations in concentrations for different elements is not statistically significant.

3.3. Soil Routine Parameters

The routine soil parameters of pH, organic matter (OM), Nitrogen (N), Potassium (K), Sodium (Na), Calcium (ca) and magnesium (Mg) for soil samples from pond before and after treatment were not statistically significant (Table 4). It suffices to note that the soil samples from pond containing wastewater before treatment (the drill cuttings pond) had significantly high levels of oil & grease. This could be attributed to the oil & grease levels leaching from the contained wastewater to the soil before its treatment. Soils which indicate accumulation of oil and grease up to 200 mg/kg (as indicated by soil sample A) within the first 20-cm of depth may consequently lead to a significant reduction in the soils ability to transmit water.

3.4. Water Quality Parameters

The results for some selected wastewater effluent parameters after treatment are shown in Table 5. The suitability of the wastewater for discharge is evaluated with the Sudanese and NEMA (National Environmental Management Agency-Uganda) discharged standards.

Table 3. Soil trace elements and heavy metals in soils before and after treatment

Sample No.	Cu	Zn	Fe	Mn	Cr	Co	Ni	Pb	Cd
	ppm (mg/kg)								
A	0.64	5.35	106.5	55.5	9.39	0.00	0.00	0.01	0.05
B	1.93	7.11	122.7	26.8	5.56	0.00	0.00	0.02	0.02
Normal Ranges	**0.1-3.0**	**1-40**	**50-1000**	**5-500**	**0.1-20.0**		**0.05-5.0**	**0.2-2.0**	**0.03-0.3**

Notes: A-Soil where untreated wastewater is collected; B-Soil where treated wastewater collects.

Table 4. Soil routine parameters before and after treatment

Sample No.	pH	OM	N	Av.P	K	Na	Ca	Mg	Oil and Grease
		%ge		ppm	Cmoles / kg				mg/kg
A	9.7	1.89	0.12	69.5	1.01	2.46	35.5	4.9	338
B	9.3	4.78	0.21	3.25	1.23	2.15	36.5	6.7	nd

Notes: A-Soil where untreated wastewater is collected; B-Soil where treated wastewater collects; nd-Not detected (detection limit for oil & grease = 0.1 mg/kg).

Table 5. Water routine parameters before and after treatment

Paramete	Units	Sample A	NEMA Effluent standards*	Sudanese Guidelines for Discharge
pH		9.1	6.0-8.0	6.0-9.0
EC	µS/cm	804	ns	
TDS	mg/l	404	1200	
Temperature	°C	28.1		
Apparent Colour	PtCo	934	ns	
Sodium		65.2	ns	
Aluminium	mg/l	0.51	0.5	25
Chlorides	mg/l	400	500	
Nitrates	mg/l	nd	20	30
Potassium	mg/l	20.3	ns	
Sulphate	mg/l	24	500	
Total Phosphorus	mg/l	0.42	10.0	
Carbonate	mg/l	100	ns	
Total Iron	mg/l	12.3	10	1
Cadmium	mg/l	0.12	0.1	0.01
Calcium	mg/l	32.0	100	
Chromium	mg/l	0.23	1	0.05
Zinc	mg/l	0.21		1
Barium	mg/l	1.2		2
Copper	mg/l	nd	1	1.5
Ammonium	mg/l	1.5		
Oil and grease	mg/l	38	10	

Notes: * Uganda National Effluent discharge standards, 1999-values for heavy metals are for total concentrations; ns-not specified; n.d-not detected; detection limit for total phosphorus is 0.004mg/l; detection limit for total iron, Cadmium, Chromium, Lead, Manganese and Nickel is 0.001mg/l.

The effluent wastewater largely complies with both the Sudanese Guidelines for discharge and the Ugandan effluent discharge standards [17] except for Total iron, Cadmium, Chromium, and Oil & grease (for some sources, cells with grey highlight). The Sudanese guidelines took precedence wherever the parameters are present, or else, the Ugandan guidelines was used for missing parameters from the Sudanese guidelines. The high total iron levels may contribute to the colouration of the wastewater and causes undesirable taste in beverages, stains sanitary ware and laundry, if it leaks into drinking water sources. Similarly, spillage of the high cadmium levels into drinking water can lead to kidney damage (due to accumulations of cadmium).The sampled wastewater exhibited levels of oil and grease which beyond the stipulated guidelines (>10mg/l). This is indicative of the fact that the sampled wastewater contains some oil & grease residuals.

4. Conclusion

The results generally show that a number of wastewater effluent parameters from the drill cuttings fluid are within the allowable discharge standards, hence a reflection of the adequacy of the treatment plant. The visibly grey colour of the treated effluent (Figure 2, Table 5) is a result of clayey soils. That is the possible reason for the greyish appearance.

The effluent from the treatment plant has some low levels of oil & grease and also no oil & grease was found in the soils containing the effluent. This is either a further explanation of no problems with the receiving soils as a result of oil & grease concentrations in effluent or the plastic lining in the receiving pond being effective (Figure 2). Therefore, the treatment plant performs well in regards to oil & grease reduction/removal.

The rest of the effluent parameters could not be easily predicted with the available information, but the fact that most of the parameters in wastewater meeting the discharge standards is a reflection of an efficient treatment plant.

Acknowledgements

The authors wish to acknowledge all the entire staffs of the Department of Environmental Studies, College of Natural Resources and Environmental Studies, University of Juba, management of DPOC and Eco-consultancy Ltd, Juba. Acknowledgment is made to all members for their contribution in this research study.

References

[1] Soroush Ghasemi, Saeid Gitipour, Fereydoun Ghazban, Hamed Hedayati (2017). Treatment of Petroleum Drill Cuttings Using Stabilization/Solidification Method by Cement and Modified Clay Mixes. Iranian Journal of Health, Safety & Environment, Vol.4, No.3, pp.781-787.

[2] S.A.S. Boards. Oil & Gas Exploration & Production. San Francisco: Sustainability Accounting Standards Boards; 2014.

[3] Al-Ansary MS, Al-Tabbaa A. Stabilisation/solidification of Synthetic Petroleum Drill Cuttings. J. Hazard. Mater. 2007; 141(2): 410-21.

[4] Conner JR. Chemical Fixation and Solidification of Hazardous Wastes. Springer Netherlands; 1990.

[5] Malviya R, Chaudhary R. Factors Affecting Hazardous Waste Solidification/stabilization: A review. J. Hazard. Mater. 2006; 137(1): 267-76.

[6] U.S. EPA. Technology Performance Review: Selecting and Using Solidification/stabilization Treatment for Site Remediation. US Environmental Protection Agency; 2009.

[7] U.S. EPA. Technical Resource Document Solidification-stabilization and Its Application to Waste Materials. US Environmental Protection Agency; 1993.

[8] Lin SL, Cross WH, Chian ESK, Lai JS, Giabbai M, Hung CH. Stabilization and Solidification of Lead in Contaminated Soils. J. Hazard. Mater. 1996; 48(1-3): 95-10.

[9] Kogbara RB, Ayotamuno JM, Onuomah I, Ehio V, Damka TD. Stabilisation/solidification and Bioaugmentation Treatment of Petroleum Drill Cuttings. Appl. Geochemistry. 2016; 71: 1-8.

[10] Singh TS, Pant KK. Solidification/stabilization of Arsenic Containing Solid Wastes Using Portland Cement, Fly Ash and Polymeric Materials. J. Hazard. Mater. 2006; 131: 29-36.

[11] Yong R. Geoenvironmental Engineering, Contaminated Soils, Pollutant Fate, and Mitigation. CRC Press; 2000.

[12] Morillon, A., J.F. Vidalie, U.Syahnudi, S. Suripno, and E.K. Hadinoto, 2002, " Drilling and Waste Management, " SPE 73931, presented at the SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Kuala Lumpur, Malaysia, March 20-22.

[13] BMT Cordah Limited, 2002, "Use of Oil Drilling Wastes in Civil Engineerin Applications" report no. COR027/Programme/2002, September.

[14] Shafer, G.P., M.W. Hester, S. Miller, D.K. DesRoches, R.F. Souther, G.W. Childers, and F.M. Campo, 1998, " Restored Drill Cuttings for Wetlands Creation: Results of a Two-Year Mesocosm Approach to Emulate Field Conditions under varying Hydrologic Regimes," DOE/BC/14849-3, Preared by Southeastern Louisiana University Wetlands Restoration Laboratory, Hammond, LA, for U.S. Depart of Energy, National Petroleum Technology Office, November.

[15] APHA/AWWA/WEF (2012). Standard Methods for the Examination of Water and Wastewater. 22nd. ed Washington DC, USA. ISBN 978-087553-013-0.

[16] Okalebo, J. R., Gathua, K. W. & Woomer, P. L. (2002). Laboratory Methods of Soil and Plant Analysis: A Working Manual. Nairobi, Kenya.

[17] NEMA (1999). The National Environment (Standards for Discharge of Effluent into Water or on Land) Regulations, S. I. No 5/1999. Kampala, Uganda.