

Field Trials for the Treatment of Potassium Silicate based Drilling Waste using Calcium Humate

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Abstract

Drilling waste salinity plays a pivotal role in determining the disposal method and subsequent cost. On-site and/or surface disposal methods represent the preferred options for land-based drilling. To preserve the quality of soil, drilling waste must not adversely increase background soil salinity. Regulators typically measure salinity using the criteria of:

- sodium content,
- electrical conductivity (EC), and
- sodium adsorption ratio (SAR).

A major challenge for water based drilling fluids is on the need to provide adequate shale inhibition without producing drilling waste with excessively high salinity. Potassium silicate has been proven a highly effective shale inhibitor with lower EC values versus other commonly used potassium additives. However, SAR of potassium silicate drilling waste is typically high. It can be lowered using gypsum and/or epsom salts. However, this results in the increased of EC.

This paper reviews a technical collaboration between suppliers, service companies and operators that led to the development of a superior waste amendment. This new product is derived from humate, defined as natural material rich in humic acids, macromolecular organic matters with a great affinity to cations. Calcium humate has been designed to improve the salinity of water-based drilling waste, and more specifically, potassium silicate based drilling waste.

Introduction

In the United States, Canada and Mexico, potassium silicate is a commonly used drilling fluid additive. Its stabilization properties and HS&E characteristics have well been documented^{1,2,3,4}. In addition, it is registered as a fertilizer⁵. The efficacy of potassium silicate as a drilling fluid additive (and fertilizer) is linked to the soluble potassium (K_2O) and silica (SiO_2). Compared to other potassium-based drilling fluids, silicate systems have lower electrical conductivity values (Figure 1)⁶. However, the silicate component precipitates soluble calcium and magnesium in the waste, resulting in higher SAR values. Historically, SAR has been lowered by the use of gypsum and/or epsom salts. However,

the decrease in SAR comes at the expense of higher EC due to the presence of soluble sulfates in the waste.

The equation below illustrates the importance of preventing the build-up of soluble sodium and the importance of maintaining or increasing soluble calcium and/or magnesium in order to minimize the SAR.

$$SAR = \frac{[Na^+]}{\sqrt{\frac{1}{2}([Ca^{++}] + [Mg^{++}])}}$$

Na = sodium (meq/L)
Ca = calcium (meq/L)
Mg = magnesium (meq/L)

Calcium Humate

Over the last decade, there has been resurgence in the use of humate in agriculture. Humate is natural organic material rich in humic acids. Humic acids are defined as natural macromolecular organic matters of carboxylic (COOH), phenol-OH and quinonic (C=O) groups (Figure 2)⁷. The colloidal nature of humate also improves the quality of soil. Humate enhances the growth of plant and soil organisms. It has a great affinity to cations (also known as the cation-exchange-capacity, or CEC), making it an excellent natural bonding agent to common nutrients in agriculture^{7,8}. Particularly, humate remediates high-salinity soil⁹, which serves for the evaluation of this technology for drilling waste.

In this work, weathered sub-bituminous coal has been selected as the type of humate. It is similar to leonardite (weathered lignite) but of a better quality due to its lower impurities^{10,11}. It has different characteristics than those of the ordinary coal (anthracite or bituminous), such as a lower energy value¹¹, and therefore used in different applications¹². This material is considered to be non-hazardous¹³ and registered as a soil amendment¹⁴. The weathered sub-bituminous coal itself is not readily soluble in water and therefore humic acids contained in it cannot effectively be utilized. This condition can easily be reversed by raising its pH to 7. A typical weathered sub-bituminous coal has a CEC of over 600 meq/100 g¹¹.

Calcium humate is a blend of calcium and the weathered sub-bituminous coal. Calcium is added to raise its pH to around 10, and when combined with humate, to provide a source of chelated calcium. When the treated drill cuttings are mixed with background soil, the alkalinity of the drill cuttings is reduced and the final pH closely mirrors that of the indigenous soil. It is thought that an equilibrium reaction is established for CEC based on drilling waste soil conditions. Humic acids deplete soluble silica, releasing small amount of soluble calcium or magnesium already present in the waste. This results in the reduction of SAR, while maintaining or slightly increasing the EC.

Laboratory Studies

Samples of potassium silicate drilling fluid, drilling waste and subsoil were obtained from numerous well sites in Western Canada. Lab studies compared calcium humate against untreated and treated drilling waste with traditional amendments of gypsum and epsom salt. Testing showed that calcium humate reduced soluble sodium, had a minimal effect on EC and substantially reduced SAR.

Current amendments are effective at depleting soluble silica but have the disadvantage of adversely effecting drilling fluids properties. They are usually added at well completion. Laboratory studies looked at the effect of calcium humate on the drilling fluid properties (Tables 1a,b). It was found that a moderate amount of calcium humate can easily be dispersed into an active drilling fluid with no adverse effect on its rheology or fluid loss. By adding calcium humate to an active potassium silicate drilling fluid, it is easier to deplete the soluble silica, allowing soluble calcium and magnesium buildup in the drilling fluid.

After a number of laboratory studies had confirmed the reduction of SAR while maintaining or slightly increasing the EC, Argosy Energy was approached to assist in the development of this technology.

Case History 1

Argosy Energy used a potassium silicate based drilling fluid for two wells in Southern Alberta. The raw drilling waste would have required land filling based on salinity endpoints. Testing showed that if calcium humate was used as an amendment then the drilling waste would qualify for disposal via Mix Bury Cover. After receiving approval from the operator for a field trial, the government body responsible for drilling waste disposal (Alberta Energy Resources Conservation Board, or AERCB) was informed of the trial. Approval was granted for the calcium humate treatment pilot project.

The initial trials required that the calcium humate be post added to the drilling waste. Calcium humate was dispersed into the sump using a track hoe. Mixing took approximately two hours. The dispersion of the calcium humate could be

seen as cuttings went from a solid grey colour to a uniform brown colour. It was also noticed that the addition of calcium humate had a drying effect on the cuttings and produced a more friable mix. The estimated volume of drill cuttings was ~150 m³ for both locations. Three pallets of calcium humate (i.e. 3000 kg) were used per location. It is estimated that loading was approximately 1.35% by weight.

Prior to disposing by Mix-Bury-Cover, an independent lab verified that the treated cuttings and receiving soil would meet AERCB guidelines (Table 2).

Drill cuttings initially required disposal by class II land filling. The cost of land filling is determined by numerous direct costs (landfill tipping fees, trucking, heavy equipment rental, saw dust or similar stabilization material) and indirect costs (i.e. such as the safety of this material traveling down highways and potentially additional green house gas emissions). It was estimated that the cost of using calcium humate and on-site disposal was less than 25% the cost of disposing at an approved waste management facility.

Case History 2

Based on the success of the first trials, the operator asked that calcium humate be used at three upcoming wells to be with a potassium silicate-based drilling fluid. For these wells, 2 pallets of calcium humate were used per well site. Samples were taken at two different depths both pre and post treatment with calcium humate. The results were consistent in demonstrating improvement in SAR with minimal to moderate increase in EC (Tables 3a,b,c). It was also observed that the dry bulk density was statistically lower for waste treated with calcium humate. A reduction in dry bulk density is beneficial as it results in lower mass loading of the individual material.

Compared to the first set of trials, the second series had a couple of inherent advantages. Mechanically, the amendment could be added to drill cuttings pile as it was being generated. This resulted in greater and more uniform dispersion of the amendment while saving the costs associated with a post treatment. Chemically, as potassium silicate-based drilling waste ages, there is a natural attenuation of soluble silica (SiO₂⁻²) and results in a gradual loss of pH. The higher pH found in "fresh" drill cuttings would result greater cation exchange in the humic material. The amount of calcium humate used for the second trials were reduced by a pallet with no adverse effect.

Government approval was given to dispose cuttings on site via the Landspray for 03-35 and 07-13 locations and Mix Bury Cover for 08-05. Potassium silicate drilling fluid was disposed via the landspray disposal option.

Conclusions

Laboratory and field testing has focused on understanding the chemical impact of adding calcium humate to potassium

silicate based drilling waste. The information collected to date indicates that:

- a moderate amount of calcium humate can be added directly to the drilling fluid with no adverse effect on drilling fluid properties,
- the cation exchange capacity of calcium humate has proven effective at reducing sodium adsorption ratio while having a minimal effect on electrical conductivity,
- reduction in salinity is greatest under conditions of higher pH, and
- reduction in salinity should help divert waste that would otherwise need to be landfilled.

Future work will look at possible improvement to soil structure and plant growth from a holistic approach for shallow on-lease methods such as landspreading. A brief look at other forms of drilling waste suggests that humic material may also be effective at reducing the salinity of non-silicate based drilling waste.

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Nomenclature

SAR – Sodium Adsorption Ratio

EC – Electrical Conductivity

AERCB – Alberta Energy Resources and Conservation Board

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Tables

Table 1a: Fluid Loss vs. Calcium Amendment

	Fluid Loss (ml)
Control	8.3
+1% calcium humate	9.2
+1% gypsum	20.2
+1% hydrated lime	15.0

Table 1b: Rheology vs. Calcium Amendment

	600 rpm	300 rpm	200 rpm	100 rpm	6 rpm	3 rpm	10 sec gel	10 min gel
Control	42	30	25	18	5	4	6	6
+ 1% calcium humate	45	32	25	18	5	4	6	6
+1% gypsum	81	58	48	36	13	11	12	13
+1% hydrated lime	65	47	39	29	10	8	10	11

Note: 1% wt/wt , shear mixed and tested after ~ 24hrs at room temperature

Table 2: First Trial Results

Parameter Tested	Receiving Soil	Pit #3 Drilling Waste (as received)	Pit #3 Drilling Waste (1% Calcium Humate)	Post Disposal (Soil:Waste = 5:1)
Microtox EC (50) 15- charcoal	n/a	> 81.9	n/a	n/a
SAR	2.66	86.3	26.2	4.89
EC (as received)	4.39	5.51	5.74	4.47
pH (as received)	7.9	9.6	9.6	8.0
Potassium (mg/l)	11	580	737	268
Sulfate (mg/l)	2600	879	996	2960
Sodium (mg/l)	305	974	1100	457
Calcium (mg/l)	516	8	123	332
Magnesium (mg/l)	291	1	6	201
Nitrogen Total	13.32	<0.037	<0.037	4.9
Chloride (mg/l)	17	181	211	46
SG (as received) g/cm ³	1410	1480	1490	1680
Soil category	Fair			

Table 3a: Second Trial Results (Well #03-35)

Parameter	Well # 03-35-011-26W4			
	1000 meter Untreated	1000 meter Treated	2000 meter Untreated	2000 meter Treated
pH	n/a	n/a	10.9	11
EC	n/a	n/a	8.2	8.47
Chloride	n/a	n/a	490	292
Sulfate	n/a	n/a	1860	1420
Calcium	n/a	n/a	7	10
Potassium	n/a	n/a	904	2180
Magnesium	n/a	n/a	1	2
Sodium	n/a	n/a	1710	1480
Specific Gravity	n/a	n/a	1810	1540
Nitrite Soluble	n/a	n/a	<1	<1
Nitrate Soluble	n/a	n/a	<1	2
Dry Bulk Density	n/a	n/a	1300	867

Nitrate - N	n/a	n/a	<1	<1
Nitrite - N	n/a	n/a	<1	2
SAR			160	112

Table 3b: Second Trial Results (Well #07-13)

Parameter	Well # 07-13-011-26W4			
	1000 meter Untreated	1000 meter Treated	2000 meter Untreated	2000 meter Treated
pH	10.4	10.7	10.6	9.8
EC	3.9	5.54	6.32	6.55
Chloride	238	231	424	503
Sulfate	659	979	936	1680
Calcium	12	52	11	308
Potassium	330	961	455	610
Magnesium	2	3	1	8
Sodium	745	841	1250	1320
Specific Gravity	1850	1540	1870	1790
Nitrite Soluble	<1	<1	<1	<1
Nitrate Soluble	<1	2	1	<1
Dry Bulk Density	1370	867	1400	1270
Nitrate - N	<0.022	0.452	0.226	<0.022
Nitrite - N	<0.015	<0.015	<0.015	<0.015
SAR	52.4	30.7	96.7	20.3

Table 3c: Second Trial Results (Well #08-05)

Parameter	Well # 08-05-011-26W4			
	1000 meter Untreated	1000 meter Treated	2000 meter Untreated	2000 meter Treated
pH	10.4	10	10.8	10.9
EC	3.91	4.81	9.43	11
Chloride	228	137	389	381
Sulfate	593	994	1480	1310
Calcium	22	163	9	21
Potassium	268	645	1430	1980
Magnesium	2	8	1	1
Sodium	785	852	1780	1620
Specific Gravity	1770	1590	1860	1800
Nitrite Soluble	<1	<1	<1	<1
Nitrate Soluble	2	2	<1	<1
Dry Bulk Density	1240	948	1380	1280
Nitrate - N	0.452	0.452	<0.022	<0.022
Nitrite - N	<0.015	<0.015	<0.015	<0.015
SAR	42.9	17.7	150	78

Figures

Figure 1: Electrical Conductivity of Potassium Chloride vs. Potassium Silicate (EcoDrill® 317)

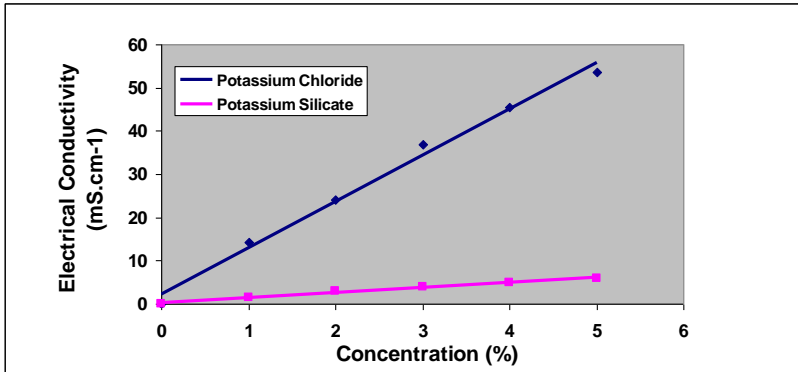


Figure 2: Model of Humic Acids

