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Research article

Pilot tests of microbe-soil combined treatment of waste drilling sludge

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Abstract

Microbe-soil combined treatment is a newly developed technology in view of the defects of the curing process and waste drilling mud slag properties. In particular, 0.3%–0.5% bioremediation reagents were fully mixed with the waste drilling sludge according to its wet and dry degree, and 1.5 folds to twice weight of more finely ground soil was added in the mix, which was covered by soil of 5–15 cm thick and thereby grasses or greeneries were planted on the soil. The process was successfully applied to some fields of Well Danqian 001-8, Well Lianhua 000-X8, etc. After three months of such treatment, the main indexes of the drilling solid waste such as the degradation of COD and the oil-degrading ratio reached more than 90%, the index of leaching solution met the requirement of the first grade in the national "*Integrated Wastewater Discharge Standard*"; heavy metal ion concentration in soil did not change significantly with the indicators meeting the requirement of the third grade in the national "*Soil Environmental Quality Standard*" (Dry Land); and no harmful effects of heavy metals have ever been found on the planted grasses and greeneries. In conclusion, with this microbe-soil technology, the soil property will recover its background values without any other chemical additives, realizing the ecological restoration and reuse of land covered by wellsite wastes, so it is in line with the energy-saving and environmentally-friendly treatment way.

Keywords: Drilling; Waste mud; Waste sludge; Microbe-soil; Combined treatment; Treatment process; Chemical oxygen demand (COD); Oil; Heavy metals; Standard

1. Introduction

At present, direct landfill or curing is mainly adopted to dispose of the solid waste generated in oil and gas drilling in China. Since waste drilling sludge contains a great amount of organic and inorganic pollutants, direct landfill would result in severe contamination and damage to surface water, underground water and soil. Curing process is a method widely used in onshore oil/gas fields, especially in the Sichuan Basin, which involves adding hardening agent such as cement in the waste drilling sludge to convert it into soil or solids with high cementing strength, which are buried on the spot or used as constructional material. In this way, the contamination damage of waste drilling sludge can basically be solved for a short period. Technically, through solidification, the absolute majority of contaminants in the drilling fluid sludge are fixed in the solidified blocks, so effective treatment can be achieved on the waste drilling sludge. However, in the long run, this curing process only fixes the pollutants in the solidified blocks, rather than completely counteracts them. When buried underground for a long time, the solidified blocks under physical, chemical and biological actions, will undergo a series of variations, and thus result in formation pollution. From the perspective of resources utilization and sustainable development, curing process consuming substantial resources and raw materials, is not an energy-saving disposal mode. Furthermore, the solidified land will lose cultivation value due to the change in soil structure. Therefore, curing process has intrinsic defects such as not really saving and recycling resources,

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and not conforming to the requirements of the national energy-saving and sustainable development policy.

Harmless treatment of waste drilling sludge has been paid attention to both at home and abroad. Early in the 1970s, in order to solve the pollution of soil by oil leaked or spilled due to the failure of oil pipelines and storage tanks, American Esso Research and Engineering Company started to hunt for clean biological solutions, and found an effective "bacteria-seeding method" in laboratory research, which set a precedent of biological remediation of soil polluted by oil [1]. The biological remediation technology of contaminated soil has drawn increasingly attention since the 1980s; it has also made great progress and become gradually mature. Some American drilling companies built biological treatment pits near the wellsites before drilling, where the wood cuttings and sawdust were used as biological bacteria culture carrier to cultivate bacteria ahead of drilling; in the course of drilling, waste drilling sludge, when produced, was sent into the biological treatment pit of wood cuttings and sawdust for remediation treatment [2–6].

2. Major property of waste drilling sludge

With the rapid development of China's economy, the energy demand is increasing constantly, and oil and gas, as the major energy resources, have become one of the major motivations in the economic development of China. However, in the course of oil and gas drilling, about 200–4000 m^3 waste water in a well would be generated depending on the drilling depth from 1000 m to 7000 m, and about 100–1000 m^3 waste sludge in a well would be generated during waste water treatment, together with the waste drill cuttings and waste drilling sludge, would end with the drilling solid waste (waste drilling fluid, sludge, drill cuttings, etc.) of 500–2500 m^3 a well depending on well depth (about 0.30 m^3 per meter of drilling). The waste sludge with all the pollutants in the drilling waste water concentrated in, is very high in contaminant concentration, e.g. COD can reach as high as 10000–50000 mg/L, content of heavy metals like Cd, Pb, Cu, As, Hg and Cr^{6+} is relatively low; SS can reach as high as 20000 mg/L. Besides, the sludge contains a certain amount of oil and different components and is usually dark brown.

1) Waste drilling fluid: mainly comes from the discarded contaminated drilling fluid and drilling fluid which is not transferred and recycled at completion. Its volume differs in different wells, and about 50–200 m^3 a well may generally be generated by a drilling crew. Because drilling fluid is usually prepared with 20–40 kinds of different inorganic and organic drilling fluid additives, including clay, drill cuttings, weighting materials, various chemical additives, inorganic salt and oil, so it is a multiphase stable suspension mixture very complicated in composition, with generally pH value as high as 8.0–10.0, higher content of harmful organic and inorganic pollutants, and COD as high as 20000–60000 mg/L.
2) Waste sludge: mainly originates from drilling fluid tank clearing and waste water treatment. Its volume, closely related to waste water treatment volume and well depth, and generally stands at 200–1500 m^3 a well by a drilling crew. The sludge produced from drilling fluid tank clearing has similar properties with the waste drilling fluid, but the sludge resulted from waste water treatment concentrates all the contaminant components in the waste water. Therefore, the waste sludge is also very complicated in composition, with a pH value usually of 8.0–9.0, a certain amount of harmful organic and inorganic pollutants, and a COD of 5000–20000 mg/L.
3) Waste drill cuttings: mainly originate from formation cuttings. Its volume, differing with various well depths, is about 200–800 m^3 a well generally in a drilling wellsite. Waste drill cuttings, usually carrying drilling fluid, have the same polluting property of drilling fluid, only with lower contaminant contents.

All these three kinds of drilling solid wastes are very harmful to the environment.

3. Principle of microbe-soil combined treatment of waste drilling sludge

It is well-known that microbes possess very strong metabolic diversity, participating in the material cycle and energy metabolism in nature. So, they have a great potential in degrading wastes, possessing such advantages as rapid decomposition, low cost, thorough degradation, enabling the reutilization of wasted resources; by converting some complicated organic matters in the waste drilling sludge into humus component, degrading some others into simple inorganic matters or even CO_2 and H_2O, they can remove the contaminants in the waste drilling sludge and make the waste drilling sludge harmless.

Soil is basically composed of soil grain, water, air and other minute associations of plants and animals, in other words, soil is composed of three types of matters: solid, liquid and gas [7]. Solid matter consists of minerals, organic matters and microbes, etc. The humus in soil generally accounting for 85%–90% of the total volume of soil organic matter, can stimulate the activity of soil microbes, and thus is favorable for the microbial metabolic activity. There are a great many sorts of microbes in soil, including bacteria, fungi, actinomycete, alga and protozoa, etc., and they are in huge numbers too, about hundreds of millions to tens of billions of microbes in 1 g soil. Microbes can decompose organic matters and minerals as well as fix nitrogen in soil. Soil air can improve the soil aeration status, which is favorable for the action of aerobic bacteria, and can stimulate the growth of plants.

Based on the soil composition property and performance, it can stimulate the action of microbes, therefore, microbes and soil have a synergistic effect, and the combination of them is can improve their capacity of contaminant degradation [8].

4. Domestication and cultivation of microbial degradation bacteria

The domestication and cultivation process of microbial degradation bacteria used for waste drilling sludge disposal is