Research and application for the non-landing treatment technology of water-based drilling solid-liquid waste in Northwest China

Bo Zhou¹,², Xiaolong Lian¹,², Lin Hou³, Biao Lei³, Lei Huang¹,², Nan Sun¹,²,
Bo Zhou⁴,*
¹Hefei General Machinery Research Institute Co., Ltd, Hefei 230031, China
²He Fei Tongyong Environmental Control Technology Limited Liability Company, Hefei 230031, China
³China Oilfield Services Limited, Langfang 065201, China
⁴Department of Applied Chemistry, Northwest Polytechnic University, Xi’an 710129, China

*Corresponding author e-mail: zhoubo@nwpu.edu.cn

Abstract. Water-based drilling solid-liquid waste is the most common environmental pollutant in the process of oil and gas exploration and development. Due to leakage or untreated discharge, these drilling solid-liquid wastes enter the atmosphere, water bodies, and soil, and cause serious pollution to the surrounding ecological environment. At present, how to reduce the heavy metals and other toxic and harmful components in water-based drilling solid-liquid waste, make it meet the discharge standards or recycle it is a major problem that plagues the sustainable development of oil and gas fields. This article introduces the sources and characteristics of water-based drilling solid-liquid waste, summarizes the domestic research status of solid-liquid waste treatment technology for foreign water-based drilling, analyzes the characteristics and advantages of drilling waste non-landing technology treatment. It is pointed out that it is necessary to adopt drilling water-based solid-liquid waste non-ground treatment technology in the exploration and development process of oil and gas fields in Northwest China, and it has good application prospects.

Key words: Drilling, Solid-liquid waste, Non-landing technology, Harmless, Environmental protection

1. Introduction
In recent years, with the continuous development of economy, the demand for energy such as oil and natural gas is increasing. Due to the wide distribution of well sites in most oil and gas fields, scattered drilling operations, open construction and seasonal influences, drilling wastes need to be recovered and treated in a centralized manner. Therefore, in oil and gas exploration and development, a great deal of drilling waste will be produced. The drilling waste mainly includes solid-liquid waste, such as oil, water, clay, cuttings, flocculants and drilling fluid additives. According to relevant research,
drilling a 3000-4000 m oil and gas well can produce 3000 m³ of solid-liquid waste. By 2020, about 20 million tons of drilling solid-liquid waste would be produced by Chinese oil and gas fields each year. However, the drilling solid-liquid waste stored in the well sites’ storage pool will cause serious pollution to the surrounding water, soil and the surrounding ecological environment due to leakage, overflow or untreated discharge. Oils, salts, chemical additives, heavy metals (such as Hg, Cu, Cr, Cd, Zn and Pb), high molecular organic compounds and alkaline substances in the drilling solid-liquid waste pose potential threats to the ecological environment and human health. The drilling solid-liquid waste is one of the main pollution sources of oil and gas fields. At present, reducing the toxic and harmful components in solid-liquid waste and making it to the discharge standard is a major problem that plagues the sustainable development of oil fields.

With the development of drilling technology, the difficulty of exploration and development continues to increase, the composition of drilling solid-liquid waste becomes more complex, and the separation of solid-liquid becomes more difficult. Moreover, the solid-liquid waste generated during the drilling process is discharged into the well site’s storage pool, which poses a potential threat to the surrounding environment and wastes drilling fluid. In the process of oil and gas exploration and development, the drilling solid-liquid waste can be divided into three types: oil-based solid-liquid waste, water-based solid-liquid waste and synthetic-based solid-liquid waste. The water-based solid-liquid waste is the most widespread drilling solid-liquid waste during oil and gas exploration and development. With the improvement of environmental protection laws and regulations of China, especially since the implementation of the new Environmental Protection Law of China in 2015, the environmental protection requirements of local government have increased, and oilfield environmental protection awareness has enhanced. Therefore, it is necessary to strengthen the research on the harmless treatment technology of the water-based drilling solid-liquid waste, especially in Northwest China with a fragile ecological environment. The non-landing technology for water-based drilling solid-liquid waste is a resource-economical and environment-friendly technology.

2. Sources and characteristics of water-based drilling solid-liquid waste

2.1. Sources of water-based drilling solid-liquid waste
The main source of water-based drilling solid-liquid waste is slurry, drill cutting and waste fluid produced in the process of drilling well. The slurry is mainly derived from the discharge of waste drilling fluid in the process of drilling well and cementing well; the drill cutting is mainly produced in the drilling process, which is mainly solid particles, and a small part of that exists in the slurry in the form of slurry sand; the waste fluid is mainly the cleaning liquids and sewage from various equipment in the exploration process of oil and gas fields. According to the source, composition and characteristic of pollutants, water-based drilling solid-liquid waste can be divided into drill cutting and slurry. It is estimated that the proportions of drilling cutting and slurry are 65% and 25%, respectively. The drilling cutting and slurry together account for over 90% of the total drilling solid-liquid waste. The harmless treatment of water-based drilling solid-liquid waste largely determines the treatment and recovery of solid-liquid waste in the process of oil and gas field exploration and development.

2.2. Characteristics of water-based drilling solid-liquid waste
Water-based drilling solid-liquid waste is a kind of mixture produced during drilling and mining, mainly composed of caustic soda, bentonite, treatment agent, clay, barite powder. The water-based drilling solid-liquid waste is in an alkaline and viscous fluid state, which is characterized by complex composition, high stability, small particles, high viscosity, high biological toxicity, and difficulty in subsequent treatment. Compared with oil-based drilling solid-liquid waste, the water-based drilling solid-liquid waste has a wider application range, larger output, faster transport and diffusion in the soil and water environment, making people pay attention to its treatment technology and environmental effects.
Water-based drilling solid-liquid waste contains more heavy metal ions, inorganics, petroleum and various organics. The water-based drilling solid-liquid waste solution has a high pH value and COD, which easily damages the ecology and causes great environmental pollution. In the traditional treatment method, the solid-liquid waste generated during the drilling process is collected in the sewage tank, and the solid-liquid separation is achieved through water washing, reverse osmosis, segregation and evaporation, and then performs solidification treatment. However, the petroleum, organic and other organic chemicals in water-based drilling solid-liquid wastes often exist in the form of hydrated ions. Due to the constraints of drilling operations field conditions and environment, it is challenging to achieve harmless treatment through traditional treatment or have a greater risk of environmental pollution.

3. Research status of water-based drilling solid-liquid waste treatment technology

During the exploration and development of oil and gas fields, a large amount of water-based drilling solid-liquid waste will be generated. If these water-based drilling solid-liquid wastes are improperly treated or leaked, they will threaten ecological safety and human health. According to the locality, it is a challenge for oil and gas extraction companies to choose a suitable treatment method for water-based drilling solid liquid waste. At present, the treatment technologies for water-based drilling solid and liquid waste mainly include extraction method, chemical demulsification method, microemulsion cleaning method, microwave pyrolysis method, solidification method, direct discharge method, cuttings re-injection method and land farming method. The following will be the most widely used and most widely treatment technologies for water-based drilling solid-liquid waste.

3.1. Extraction method

The extraction method uses the similar compatibility principle to realize the recovery of oily substances in water-based drilling solid-liquid waste by using the solubility of solvents. Firstly, the solid-liquid waste from water-based drilling is fully extracted by using solvent. After the solid residue is settled and separated, the mixed system of oil and solvent is distilled to separate the solvent, thus realizing the recovery of oil. At the same time, the separated solvent can be reused in water-based drilling solid-liquid waste treatment, and the separated residue can be heated to remove the residual solvent, thus further improves the recovery rate of the solvent. It is worth noting that, although this method can effectively extract oily substances, the solvent recovery is usually through distillation, which consumes a lot of energy. Meanwhile, the volatile leakage of organic solvents poses a great threat to human health and the environment. Therefore, in order to reduce environmental and ecological hazards, it is necessary to develop new green solvents to treat the oil components in water-based drilling solid-liquid waste.

3.2. Chemical demulsification method

The chemical demulsification method uses surface active substances to remove oily substances through emulsification, which can avoid the problems of volatilization, toxic side effects and residue of organic solvents. Therefore, the emulsification method is also widely used in the separation of oil substances. Generally speaking, the emulsification method is conducive to the treatment of oil-based drilling solid-liquid waste. For the treatment of water-based drilling solid-liquid waste, it is necessary to separate oil from water first, and then further treat the solid waste, such as extraction treatment, curing treatment and so on. This method is used to treat oil substances in water-based drilling solid-liquid waste, which has the advantages of simple process, high oil recovery speed and low cost, but it has some problems such as low demulsification efficiency at low temperature and poor universality.

3.3. Microemulsion cleaning method

With the in-depth research on surfactants, many surfactants are difficult to maintain high surface activity under high salinity conditions. Microemulsion systems based on surfactants have gradually attracted people’s attention. Microemulsion is an isotropic thermodynamically stable system
spontaneously formed by oil, water, and surfactant, which can significantly reduce the surface tension of the solid-liquid interface and increase solubility. Compared with traditional cleaning agents, microemulsion cleaning agents have higher cleaning efficiency, and can change the wetting performance of the solid-liquid interface, and have a wide range of applications. It is worth noting that the general microemulsion can realize the removal of oily components, because of the high thermal stability of the microemulsion, it is difficult to realize the separation and recovery of oily substances. In recent years, a CO$_2$ switch microemulsion has been studied for the removal of oily components. Due to its good CO$_2$ performance, it can easily recover oily materials and has good reproducibility.

3.4. Microwave pyrolysis method
In the traditional heat treatment process, energy is transferred to the material through conduction, convection and radiation to achieve decomposition, while in the process of microwave pyrolysis, it is directly transferred to the material through the interaction with the molecules in the electromagnetic field to achieve decomposition. The internal temperature distribution of traditional heat treatment technology materials is limited by the heat conduction efficiency, while microwave heat treatment technology realizes that each unit is individually heated. Microwave heat treatment can effectively reduce the heat treatment time. Compared with incineration or conventional heat treatment technology, microwave pyrolysis technology, as an energy-saving and effective solid waste separation technology, has higher sustainability and effectiveness.

3.5. Solidification method
In the solid-liquid waste solidification process, the solid-liquid waste is solidified by adding a solidifying agent, and then buried and phytoremediated to reduce the transport and diffusion of heavy metals and other pollutants in the waste in the soil. The curing process is shown in Figure 1. It can be seen that the most important thing in the curing process is the use of curing agents, which currently mainly include two types of single inorganic curing agents and composite curing agents. The single inorganic curing agent is mainly cement, polyvinyl alcohol, glycerin, asphalt, etc., and the composite curing agent is mainly a mixture of lime, fly ash, slag, and slag. The solidification treatment technology of drilling fluid is currently the most widely used and most mature method, which is mainly aimed at solid waste, such as drill cuttings, sludge, clay, etc., for solidification and burying.

![Figure 1. Flow chart of solidification treatment of drilling solid-liquid waste](image-url)
3.6. non-landing technology

The non-ground treatment technology is to separate the water-based drilling solid-liquid waste from the soil during the drilling process, and make it harmless by adding chemicals and other means to achieve the reduction and harmlessness of the water-based drilling solid-liquid waste. On the one hand, it can recover the materials attached to the cuttings. On the other hand, it can recover the liquid phase through the principles of solid-liquid separation equipment and electrochemical adsorption. Moreover, the solid phase can also be prepared into a mud cake to achieve solidification. Water-based drilling waste non-landing technology includes waste collection unit, gel breaking treatment unit, solid-liquid separation unit. The treatment process is to dilute, flocculate, and separate the waste, and separate the solid and liquid phases. The cuttings that meet the standard can be directly discharged, washing, separation, chemical reaction, and physical drying are carried out for solidification treatment that does not meet the standard. Among them, after the organic substances enter the water phase, they can be recycled and reused after they reach the comprehensive sewage discharge standard through filtration, permeation and other processes. The technological process of non-ground treatment technology for water-based drilling solid-liquid waste is shown in Figure 2.

![Figure 2. Flow chart of non-landing treatment technology for water-based drilling solid-liquid waste](image)

The direct discharge method is an early treatment method, which is used for cuttings produced in simple water-based drilling solid-liquid waste. Due to the high environmental protection requirements, this kind of treatment method has been eliminated. The cuttings re-injection method is to grind drill cuttings into a certain viscosity liquid, then inject the mucus into the well, and then seal the well with cement. Since the mucus re-injected by this method is easy to leak through the cracks, it is easy to cause the pollution of groundwater and oil layers, and this treatment method has been eliminated. The land farming method is to mix the drill cuttings with the soil thoroughly, and through the screening and cultivation of microorganisms, the microorganisms in the soil are used to degrade the waste cuttings. This method has strict environmental requirements and a long processing time, making it difficult to apply widely. Because there are many sources and great differences of waste, the selection of treatment technology for water-based drilling solid-liquid waste needs to be adapted to local conditions.

4. Characteristics and advantages of non-landing treatment technology

4.1. Harmlessness and reduction

The non-landing technology ensures that the organic matter, heavy metals and other harmful substances in the waste drilling mud will not volatilize into the air or penetrate into the groundwater by harmless treatment of the waste drilling fluid, causing secondary pollution. At the same time, the
non-landing technology can change the physical properties of the waste drilling mud, making it from a viscous mud state to a soil-like substance quickly dewatered for further use.

4.2. Reuse of resources

The non-landing technology can not only reduce the pollution to the surrounding environment, but also create certain economic benefits by recycling or reusing the waste fluid and mud in the waste drilling mud while harmlessly treating the waste drilling mud.

4.3. Comprehensive utilization

The non-landing technology can effectively treat and improve the solid cuttings in the waste. It can be used to pave the well site, and the well can be further treated as soil for gardening and greening, so as to realize the comprehensive utilization of waste drilling mud.

5. The application prospects of the non-landing technology in Northwest China

In recent years, with the improvement of government environmental protection requirements and the enhancement of public awareness of environmental protection, many countries have put forward the goal of "zero discharge" of drilling solid-liquid waste, and strict requirements have been implemented in stages from source reduction, process control to end treatment. In order to reduce the environmental pollution of drilling solid and liquid waste and realize the comprehensive utilization of resources, thereby promoting the systematization, standardization and standardization of drilling waste treatment. Non-landing technology for drilling solid-liquid waste has become a trend in the development of drilling environmental protection. The non-landing technology can prevent heavy metals and other harmful substances in water-based drilling solid-liquid waste from entering the atmosphere, water, soil and other environments. Through reduction, harmlessness, and resource treatment, the technology can realize the minimum of environmental pollution and the comprehensive utilization of water-based drilling solid-liquid waste. At present, the non-landing technology of drilling solid-liquid waste has a certain scope of application in land and offshore oil and gas fields at home and abroad.

Northwest region is an important oil and gas reservoir, oil and gas resources account for about a quarter of China. The oil and gas fields are mainly distributed in the Tarim Basin, Junggar Basin, Qaidam Basin, Tuha Basin, Loess Plateau and Ordos Plateau. These basins and plateaus in Northwest China have an arid and semi-arid climate, with very little annual precipitation and a fragile ecological environment. In order to reduce the damage to the fragile ecological environment in the area and realize resource utilization, drilling solid-liquid waste non-landing technology has been applied in environmentally sensitive areas such as Tarim Oilfield, Qinghai Oilfield, Changqing Oilfield, Ordos Daniudi Gasfield.

6. Conclusion and suggestion

Water-based drilling solid-liquid waste is the most common waste pollutant produced the process of oil exploration and development. The composition of drilling solid-liquid waste is extremely complex, and its discharge without treatment is extremely harmful to the environment. The northwestern region of China is a hot spot for oil and gas development and production. During the exploration and development of oil and gas, a large amount of water-based drilling solid-liquid waste will be generated. The leakage or improper disposal of these solid-liquid wastes will pollute the surrounding environment and further cause hard-to-repair damage to the fragile ecosystem in the region.

In recent years, with the improvement of government environmental protection requirements and the enhancement of oilfield environmental protection awareness, the development of environmentally friendly water-based drilling solid-liquid waste treatment technology is an effective means to reduce the impact of drilling fluid on the environment and reduce the difficulty and cost of waste disposal. Therefore, in the process of oil and gas exploration and development, appropriate water-based drilling solid-liquid waste treatment technology should be selected according to local conditions, so as to reduce the toxic and harmful components in the solid-liquid waste, make it meet the standard
discharge or recycle. Non-landing treatment technology of water-based drilling solid-liquid waste is an environment-friendly technology, which can not only reduce the pollution of solid-liquid waste in the process of oil and gas exploration and development, but also realize the recycling and utilization of resources, especially suitable for areas with fragile ecological environment of oil and gas exploration and development.

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