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Remediation of Hazardous Materials with an Emphasis on NORM

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Abstract

Everyday, Naturally Occurring Radioactive Material (NORM) is produced and is a hazard for the oilfield industry. The oilfield industry releases NORM from the sub-surface to the surface during the production processes that produces water, oil and gas. Most often NORM is found in production tubing, piping, and equipment, such as tanks or heater treaters that can build up scale or store fluids. Leakage or a simple work-over can get this on the ground or on a workers clothing. If the NORM solid is inhaled or enters a human body orally, it can cause the worst type of cancer.

There are multiple ways to handle NORM waste efficiently, safely, environmentally, and cost efficiently. Handling of NORM begins during the remediation of a well or site equipment, then the waste should be minimized and securely contained and, lastly, responsibly disposed. Removal of the scale or sludge from pipe may be done using either a “Pipe cleaning Machine” or inside a “decontamination booth”. Each uses high pressure water blasting for removal of NORM and collecting the sub sequential waste in different catch systems. Waste collected may be minimized by separating out the wash water then chemically and mechanically fluidizing the NORM using a “No Moving Parts Grinder”, “Sand Wash Unit”, or a Gasification unit. Minimized or non-minimized wastes have multiple disposal options including land-farm (dilution), down-hole disposal, and encapsulation in an impermeable cell. A recent technology referred to as gasification minimizes, disposes, and produces energy in the same system. Disposal methods vary in safety and distance from public. Further, remediation, minimization, and disposal options drastically vary in cost efficiency and long term safety.

Introduction

Experience has proven that Hazardous Material handling and disposal in the oilfield industry combines safe disposal, cost efficiency, environmental impact, and public isolation for solutions. A prevalent and recently more known hazard is Naturally Occurring Radioactive Material (NORM). NORM generally found in the oilfield refers to the elements radium, radon, and uranium and calcium carbonate. As mentioned before, the oilfield industry extracts NORM (typically the radium isotope) from the sub-surface during the production process. The equipment used during production forms a scale or sludge waste coating the equipment. The scale contains the NORM; the equipment itself is not NORM. As the waste moves towards the surface, scale is formed by the changes in temperature, pressure, and salinity. This is accommodated by the natural calcium and sulfate minerals present in the sub-surface.

The quantity, thickness and presence of NORM vary per production site. The quantity usually gets greater with higher amounts and longer periods of produced water. When pipe, equipment or spillage is

found to be hot[1] the threshold for Norm handling begins. Once it reaches 50μR/hr[2] the equipment is considered NORM contaminated and strict enforcement is implemented. The main difference is the presence of radionuclides in NORM. In each state in the U.S. and many other countries, a Department of Environmental Quality (DEQ) regulates the handling and disposing of NORM. If that state does not have regulations please refer to the Environmental Protection Agency (EPA) for guidelines

Theory and Processes

When NORM has been found the first step is determine and assess the quantity and concentration of the NORM waste. Upon completion remediation may begin. Remediation removes hot equipment or ground from a given area to a designated secure hazardous waste cleaning facility. To begin remediation or decontamination, a confirmatory (or baseline) survey must be completed for adequate removal of all hot material. The confirmatory survey allows for maximum remediation with minimal removal by locating and marking all hot areas on a survey plat or other means. Too often, ground (dirt, sand, soil, etc…) that is not hot will be removed and mixed with hot ground thus increasing the overall mass of the waste and increase handling and disposal costs. Recognition of what is hot and what is not hot provides one the most important steps in the remediation and decontamination process. Companies that do not do confirmatory survey consistently pick up at least 25% more ground than necessary during removal or just because 1 pipe is hot and in the area, all pipes are removed. Surveying equipment before removal from location will decrease risk of further contamination. All equipment found hot must have the openings covered or contained to prevent spillage. After removal of ground and equipment the materials will go to a decontamination facility to remove any NORM and containerize for disposal. In instances of only ground removal the NORM may be brought directly to the disposal facility. It must be noted that if remediating a site currently being plugged and abandoned, removal of NORM from site may not be necessary.

After completion of remediation the site decontamination and minimization of the equipment and waste occurs. Many options exists 1) decontamination 2) decontamination then minimization 3) minimization on location all options followed by a disposal option. Decontamination facilities offer a wide range of technologies to remove waste from equipment. Determining if the NORM is hard Barium sulfate scale or a mix with soft calcium carbonate will allow a skilled contractor to determine cleaning methods. For joints of tubing two methods are employed in the Oilfield industry to remove waste both require a pipe cleaning machine. The first method is to use a rattler on the inside of the tubing to beat and scrap the scale off the inside of pipe. The problems with rattling include spreading of scale due to inadequate catch systems, increased inhalation risk from dust and debris, and disrupting the integrity of the pipe thus lower the reuse or resale value. The second method uses high pressure water blasting with a rotating nozzle on the inside of the tubing to remove the scale. Water blasting increases safety and effectiveness because it allows the waste to be caught in a sump tank. Also, water decreases the inhalation risk, increases the shielding[3] from NORM, and helps keep the integrity of the pipe. Decontamination of other equipment may be done using similar methods in contained areas. Instead of a pipe cleaning machine, water blasting with high pressured lance or snakes, torch cutting, heating and beating and scrapping are used to remove NORM from equipment.

Minimization of waste may be done at the original site location or at the permanent decontamination facility. For example, in Texas, Company A[4] has five tanks each with 500 barrel[5]

[1] Any μR/hr reading that is over twice background reading. Background reading ranges from 1 μR/hr to about 13μ R/hr. Once it starts to pass 13 μR/hr many environmental regulatory agencies will not accept higher background.
[2] μR/hr means micro Rentgens per hour and is the unit of measurement for NORM.
[3] Shielding represents the distance and radiation blocking that something may provide.
[4] Company A 's name has been changed for privacy.
[5] One barrel is a 55 gallon drum. Abbreviated bbls.

storage capacity on a single site. Every month they produce 600 barrels of waste and costs Company A approximately $150,000 plus for just disposal. Additional costs include: transportation costs, containerization and man hours. Company A decided to begin minimizing their waste on site using a portable minimization machine called a No Moving Parts Grinder (NMPG) and Sand Wash Machine. The combination uses a tortuous path for solids, water blasting with chemicals, implosion and circulation against tungsten carbide to reduce the particle size, fluidize Barium and Calcium and separate the solids & fluids. The contaminated sludge from the tanks enters into a vortex funnel, hit with 4 separate blasts of high pressure chemical and moves toward the main compartment. In the main compartment, chemicals and water are again sprayed at a high pressure toward the waste while the waste is revolving against strips of tungsten carbide and moves toward the end of the compartment. Then the waste passes into 3 highly heated wash machines with other chemicals and air spraying. The particles break up and the sludge separates into water, oil, and cleans sands over a shale shaker. Once the process is completed and all the waste is processed Company A had 50 barrels of fine NORM scale to reprocess or dispose. They recycled 70 bbls of saleable crude to their Heater Treater and placed 480 bbls of water into their water disposal system. That is a 90% reduction. Now their disposal cost is $25,000 with a savings of $125,000. The minimization unit may use different chemicals for increased efficiency, but all the chemical minimization attempts to remove Sulfate reducing bacteria, breaks the hydrocarbon chain molecularly and fluidizes the Barium and salts. Once the produced sand has been washed free of the scale it may be reused on site or sent to a drilling mud disposal site. The minimization unit needs at least 500 barrels of waste for use to be cost efficient. This is a drawback for smaller volumes which may still have a hefty price tag but, if large volumes are being produced or handled this option will drastically reduce the amount of waste and be very cost efficient. Thus minimization can be a very important tool. In figure 1 (pg 4) shows disposal costs of two injection wells and one encapsulation method. Note the disposal costs for each showing why minimization is so important.

Table 1. Disposal Facilities

Disposal Facility	Type	Cost Per Drum	Clean Out Fee
W. Texas	Injection well	$261.90	$150/per hr
E. Texas (Injection Well)	Shallow Well Injection	$300.00	$200/per hr
Utah	Encapsulization	$1,200.00	N/A

1 Prices do not include transportation or any other associated costs and are subject to change.
2 All information given on the graph was taken form actual companies price and rate schedules

Other minimization techniques include recent technologies like gasification, oxidation-reduction reaction chemicals, and solid/fluids separation. The main focus will be on gasification; oxidation-reduction reaction chemicals, solids/fluids separation and bioreactor cells have more prevalence for general oilfield waste and not NORM. Gasification units represent a new technology that minimizes Low and Intermediate Level Radioactive Waste (LILW). The unit is powered by Hydrogen water electrolysis technology to produce heat for the machine. The gasification unit uses a basic four step processes beginning with drying the waste, followed by gasification, melting at high temperatures (upwards of 3000 C), and finally vitrification of the waste. Drying the waste removes water and is the first reduction step; the gasification and melting process reduces the waste drastically by burning, and bottom ashes are melted together in a molten slag. During these processes filters are used to catch different particles for separation. The closed loop system with air control vent allows no harmful particles to be released into the atmosphere. On top of that this system produces zero air emissions due to its clean burning from the Hydrogen fuel. When completed the waste will be vitrified and a reduction from a ton of waste to the size of a coke can will be complete. The heat (from prior steps) recycles back into the machine for energy and can be finally captured in a boiler to generate electricity to an electricity grid. The gasification unit

can be one stop shop for minimization and disposal. Even more so it allows for re-use of the waste to produce energy for the surround community. As of yet, there is not wide spread access to these units and have only recently begun to start permitting processes inside the United States of America which disqualifies the system to be considered in disposal and minimization methods inside the States.

Even with reduction of waste it still exists and must be disposed of. The main options include land-farm, down-hole disposal, and storage (see figure 2). When considering waste disposal three things must be taken into account cost efficiency, degree of isolation from the public and environmental impact. In general, companies who produce NORM waste bring it to a disposal facility. Land-farming is one of the older methods of NORM disposal. Land-farms use a concrete or enclosed pit that the NORM waste located inside containers is placed in. In order to land-farm the waste must be diluted with absorbents so it is less harmful to the surrounding area. Adding absorbents increases the amount of waste that is being stored, thus leading to a very inefficient process that does not solve the problem but only move it for a later date. Land-farming represents a short term solution with a very low degree of isolation from the public, high environmental impact, and high cost value. Similar to land-farming is entombment and encapsulation. Entombment and encapsulation[6] take the waste and enclose in a container and store the waste. The waste is still on the surface and resonating radiation still occurs. Plus surface waste storing facilities are the highest risk and cost due to the fact that Radium- 226 has a half life of over 1600 years plus the cost of keeping it secure over that time frame.

There are other options in addition to the storage methods. Multiple down-hole disposal options exist. The first is injection wells. Injection wells can be efficient if the public drinking water can be adequately protected from it. Often work-over attempts will be made to keep up down-hole equipment and the porosity and permeability of the injection reservoir. Surface equipment like pumps require a high amount of repair. This method allows a mid to high volume of disposal depending on the depth of the injection well and the disposal companies' maintenance and operational procedures.

Table 2. Disposal Options.

Technique	Minimization Option	Transportation Costs for Disposal	Waste Capacity	Isolation from Public	Environmental Impact
Land-farm	Yes	Yes	High	Low	High
Injection Well	Yes	Yes	High	High	High to Medium
Gasification	Yes	Yes	High	Medium to High	Low
Plug & Abandonment	Yes	No	Low to Medium	High	Low
Salt Dome	Yes	Yes	High	High	Low
Storage	Yes	Yes	Low	Low	High to Medium

1 Waste Capacity is not infinite for all processes. Gasification is the closest to permanent. Salt Dome and Injection wells also have long term use and high capacity.
2 Isolation from Public may change depending on company and their safety record.
3 All disposal options may not be included. These are the most used and new technologies in NORM services.

Another unique opportunity to dispose of waste involves the plug and abandonment (P&A) of wells. If NORM or any other waste is found on a producing site, the waste may be pumped back down hole and encapsulated in the casing. During the normal plug and abandonment, a balanced NORM plug is

[6] Encapsulation of NORM may also be placed down-hole during P&A's.

pumped down-hole and remains there once the plugs are set above and below it. This effectively locks the waste into the old well. The plugged well cannot contaminate underground water and has the highest level of shielding due to the concrete plugs and distance to the top of the well so no radiation can be felt on the surface. Depending on the well bore schematics, 200-300 bbls of NORM waste can be encapsulated in a normal well-bore. If the equipment on site is NORM contaminated you can slurry the waste and pump it into the well along with the ground contamination. Tanks, heater treaters and vessels with large openings are optimal for removal by pumps into the well. The problem with removal of certain waste from equipment is some equipment namely joints or piping require other equipment to remove the scale on the inside or have a thicker NORM scale. This is rarely done (and very cost inefficient) due to the large move in and out of equipment and set up time required.

The last method is Salt Dome disposal. Salt domes are similar in method to injection wells and plug and abandonments but the waste is placed in old abandoned salt domes. This can be very beneficial and if waste is minimized will prolong the storage capacity lifetime of the salt well. Whichever NORM down-hole disposal you generally accomplish four things 1) putting the waste back where it came from 2) higher degree of isolation from public 3) saving money 4) decreased environmental impact. Other methods involve transporting, greater potential of spreading contamination, and lower isolation from the public.

Conclusion

The handling of NORM over the last 18 years has become more understood and, with newer technologies, disposal methods are slowly become more efficient. But, treatment and disposal methods still heavily rely distance to nearest disposal location. If a gasification unit is in close proximity it would provide a good option for reusing the waste and could be a huge asset to the environmental image of the oil-field industry. The Plug and Abandonment method decreases large transportation costs and solves two problems in one, but only a handful of companies are willing to do so. While surface storage and land-farming might be the only option available in your area it is important to remember the ramification. 1600 years of grandchildren will have to live with the NORM in that area.

Though, radiation and hazardous material generate negative reactions in public, given the recent advances in technology NORM can be safely removed from the publics harm. Recent advances have also allowed for improvement in the environmental sector of waste handling many of which may be used when dealing with NORM. It is important to evaluate all options when handling NORM and above all keep Public and Worker Safety as the number one priority in your decision. And to remember four important things when handling NORM waste 1) environmental impact 2) cost efficiency 3) safety 4) degree of isolation from public.

Tables

Figure 1
1 Prices do not include transportation or any other associated costs and are subject to change.
2 All information given on the graph was taken from actual companies price and rate schedules

Figure 2
1 Waste Capacity is not infinite for all processes. Gasification is the closest to permanent. Salt Dome and Injection wells also have long term use and high capacity.
2 Isolation from Public may change depending on company and their safety record.

Notes

1 Company A name has been changed for privacy.

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