Management and Disposal Options and Costs for Naturally Occurring Radioactive Material (NORM) in Oil and Gas Field Operations

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Naturally occurring radioactive material (NORM) has posed a growing concern to oil and gas field operations as states have begun to impose management requirements for these wastes. The general public is always concerned about anything that is *radioactive*, and does not readily distinguish between very low levels and those that can be dangerous to human health, which tends to lead to stringent management requirements. Disposal options for NORM waste have typically been few in number, and the cost of disposal has been quite high. With a growing focus on NORM, this has begun to change; more options are available and costs are falling. Nonetheless, NORM waste management continues to be major concern of industry and government.

This paper is designed to provide a quick overview of NORM wastes from the industry, available disposal options and costs, an overview of the major companies involved in NORM waste disposal, and information on the decision-making process for NORM waste management choices. The purpose of this paper is to provide background information on current NORM management to staff at the U.S. Department of Energy who are involved in evaluating research activities related to NORM. This information has been compiled based on a soon to be published *NORM Disposal Cost Study* by the American Petroleum Institute, discussions with companies providing NORM waste disposal services, and conversations with personnel in oil and gas companies who have responsibility for NORM waste disposal.

Source of NORM

Four primary sources of NORM contamination create NORM wastes within the industry:

- Radioactive scale (primarily Radium 226 and Radium 228) forms in well tubulars as the NORM precipitates out of solution with the produced fluids.
- Radon gas and its daughter products (e.g., lead-210) can form a film inside equipment and piping used for natural gas processing (both at gas plants and field operations).
- Soil can become contaminated when scale falls out of tubulars and mixes with the soil (both at field sites and pipe cleaning yards), or where produced fluids that still contain Radium spill or are stored in earthen pits (no longer a common practice).
- Sludges in the bottom of tanks can also become contaminated with Radium from produced fluids.

For the remainder of this paper, the latter two categories (soils and sludges) will be considered together, since the available management options are similar.

Volume of NORM Wastes

Since some of the current NORM waste volume to be addressed relates to wastes formed by prior activities or practices (soil contamination from the period before NORM was a concern, older equipment, etc.), API has estimated a 15-year accumulation of NORM waste to be disposed. API estimates this volume to be slightly more than 10 million drums (55 gallon

drums). Assuming that a drum weighs about 750 pounds, this translates to 3.4 million metric tonnes of NORM waste.

Although this predicted waste volume is large, it is not located at central sites. The oil and gas industry operates at hundreds of thousands of sites, and these wastes exist across a large number of these sites. Thus, the total volume of NORM to be handled at a given site in a single year is actually quite small. This fact can complicate management and disposal options.

NORM does not exist at all production sites, since it is a function of the underlying geology. The large producing areas along the Gulf Coast tend to be NORM-prone, as do certain areas of the Rocky Mountains.

Characterization of NORM

API has provided data on the amount of radioactivity associated with NORM wastes, as shown in the following table. This type of radioactivity is measured in picocuries per gram (pCi/g).

Specific Activity Range (Radium 226)	Percentage of Waste Stream
< 200 pCi/g	92%
200 - < 2000 pCi/g	7%
> 2000 pCi/g	<1%

Data from an unpublished study by the Louisiana Mid-Continent Oil and Gas Association (LMOGA) provides a breakdown of wastes less than 200 pCi/g:

Specific Activity Range (Radium 226)	Percentage of Waste Stream
5-30 pCi/g	53%
30-100 pCi/g	33%
100-500 pCi/g	11%
500-1000 pCi/g	2%
> 1000 pCi/g	< 1%

The threshold for covered NORM wastes in most states that have established regulations on NORM is 30 pCi/g. A level of 5 pCi/g is considered to be at or below background levels of radiation in most parts of the country. In addition, 5 pCi/g is considered to be the lower threshold of current detection equipment.

NORM Disposal Options

Six primary options are currently being used for the disposal of NORM wastes. Companies tend to prefer options that result in a complete transfer or elimination of future liability or disposal on their own property where they can manage potential liability concerns.

- Burial at a perpetual care site. This type of facility is a permitted low-level radioactive burial site. These sites must have a permanent 10,000 year care fund to provide for inspection,

care, and maintenance. This is about seven times the 1,620 year half-life of radium 226, which is the longest half-life isotope found in NORM produced with oil and gas.

- Treatment/dilution to non-hazardous oilfield waste (NOW). Treatment/dilution involves mixing NORM waste with other NOW waste or uncontaminated soil until the mixture is below 5 pCi/g of total radium. The mixture is then either released for reuse or for disposal.

- Disposal into Class II injection wells. The most recent and most promising method of disposal of NORM scale is injection into deep underground formations through oil and gas Class II injection wells. There are many under pressured formations in the oil field that could offer safe, permanent disposal. The advent of technology based on the "grind and inject" process of injecting drill cuttings has helped to make underground injection a much more viable disposal option for wastes other than water. Wastes are ground finely and injected as a slurry.

- Encapsulation in wells being plugged. This option can be used to dispose of the scaled tubing and equipment in a well to be plugged. The pipe and equipment are removed from the well, capped with cement and placed downhole in a well that is being plugged and abandoned. Even wastes with very high activity levels can be safely encapsulated in this manner. This technique has been used successfully for years. However, the limited volume of wastes that can be disposed in each wellbore, along with the need for handling the tubular goods twice makes this an expensive option.

- Landspreading with dilution on site. Diluting NORM waste and disposing it on site is allowed in some states. Texas and Louisiana allow dilution to 5 pCi/g and New Mexico allows dilution to 30 pCi/g. Dilution is a sound practice for low activity NORM materials and should not be limited to the site of origin since it may be more practical to handle the dilution at a central location.

- Smelting of NORM. Smelting of NORM contaminated equipment is especially attractive for management of equipment where the contamination can be difficult to remove (e.g., radon film on the inside of a separator or other equipment). The smelting is typically handled overseas, often in China.

In addition to these options, work is currently being conducted to study the potential use of salt caverns that have been created by solution mining in salt domes for hydrocarbon disposal. It has been suggested that salt cavern storage has potential for low cost disposal of NORM waste.

NORM Disposal Costs

Disposal Option	Cost Range (per 55 gallon drum)
Burial at perpetual care site	$300 - $700
Treatment/dilution to NOW	$100 - $325
Disposal in Class II wells	$151 - $2,300
Encapsulation in wells being plugged	$792 - $3,333
Landspreading with dilution on site	$1 - $20
Smelting of NORM	No net cost

The cost data on disposal in Class II wells, which are from the API draft report, do not properly reflect the ongoing reduction in the cost of disposal using this option. Early applications were very expensive, but as more experience is gained, costs are falling. Because of its advantages, use of this practice is growing, and companies are quickly learning to anticipate the potential problems so that this practice can be used cost-effectively.

A recent merger of two of the primary disposal companies (Newpark Resources and Campbell Wells) is creating concern in the industry that disposal costs may rise because this combined firm will control a large share of the market. Rumors of price increases have been reported, but it is too early to tell what the impact will be.

NORM Prevention

While companies have always used products to reduce the formation of scale in tubing, new products are being marketed specifically to prevent NORM scale. Chemicals that will dissolve barium sulfate scale on tubing downhole are available, but the cost of these products can often mean that it is less expensive to deal with removal of the scale after the tubing has been extracted from the wellbore. The difficulties associated with NORM scale prevention/dissolution include contacting the scale with fresh circulating chemicals and the time required to dissolve the scale.

Major Companies Involved in NORM Waste Disposal

While this is not intended to be a comprehensive list of the companies involved in NORM waste disposal, the following lists companies whose names are frequently seen in the trade press, along with the types of NORM services they provide:

- Halliburton is currently marketing a solvent/acid to dissolve NORM scale downhole.
- Suntrack focuses on training companies on how to manage their NORM wastes. They do not handle or dispose of wastes themselves.
- Apollo Well Services can assist companies with downhole disposal on NORM (slurry or encapsulation) or can facilitate transfer of NORM wastes to a commercial site for disposal. They also offer training on the management of NORM wastes.
- Newpark Resources also operates NOW sites in Louisiana and Texas. At two sites, they have permitted injection wells specifically for the disposal of NORM slurry.
- Campbell Wells operates NOW sites in Louisiana that will take low to moderate activity NORM wastes and perform dilution and disposal. [Newpark just purchased Campbell Wells; it is not clear under which name the facilities will operate.]
- Envirocare is a perpetual care site for radioactive wastes that is located near Salt Lake City.
- U.S. Ecology is a perpetual care site for radioactive wastes that is located in Oregon.

Decision-Making for NORM Waste Management

The management options available for NORM wastes differ for each of the three primary categories of NORM wastes — scale in tubulars, radon film on equipment, and contaminated soil and sludges. Several decisions are required to determine the best management method for each type of waste.

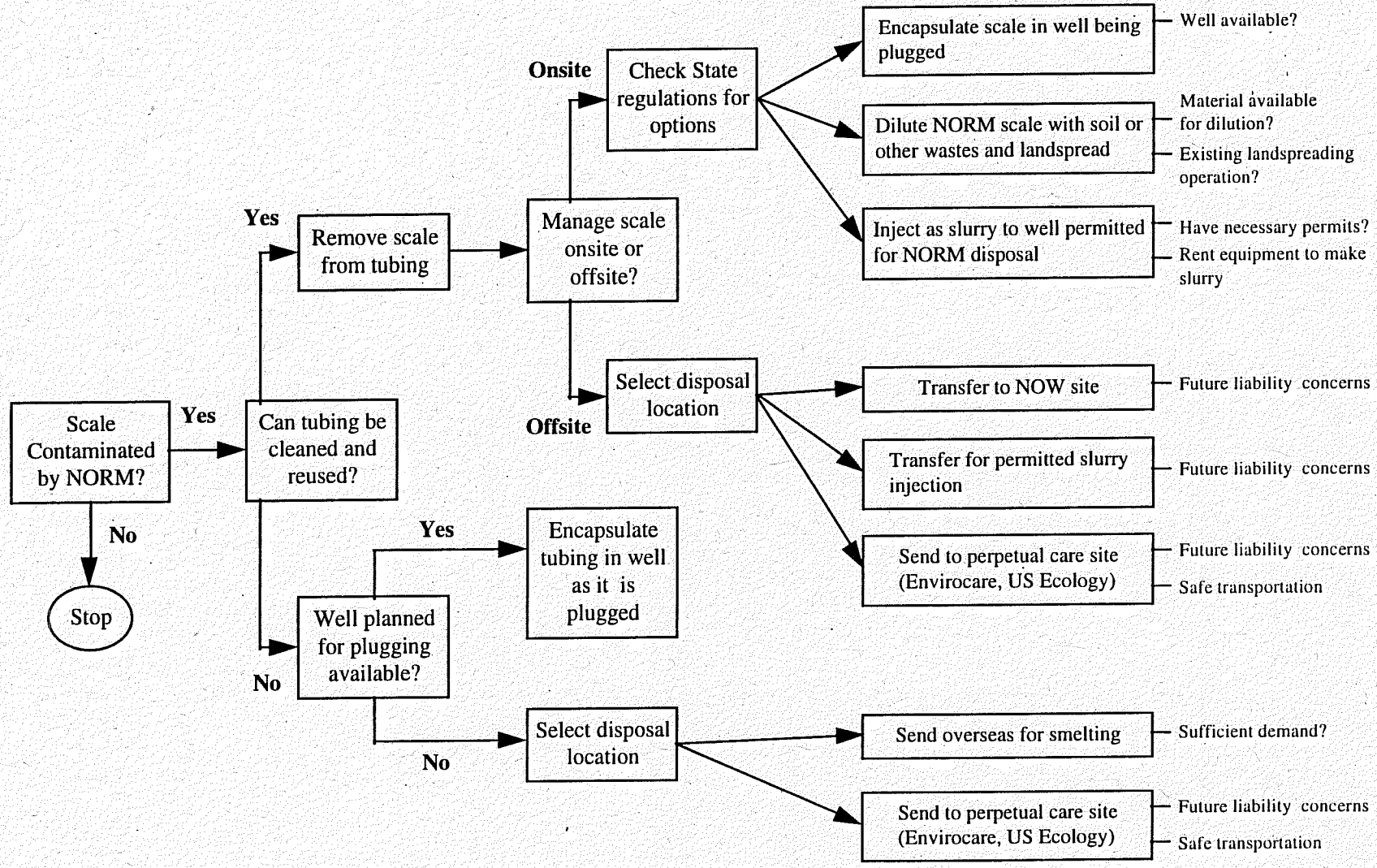
The most complex decision process is associated with NORM scale in tubulars, since the company first must decide whether the tubular can be cleaned and reused or will be disposed as is. In addition, this waste stream has the largest number of disposal options, depending on volume, location, and the company's needs. The graphic illustrates some of the key decisions required and the waste disposal options available based on those decisions. Some of the key questions that may form the basis for a company's selection among available options are noted to the right of each option.

Only three options are available to companies to address equipment that has been contaminated with radon film. The first of these is to clean the equipment to remove the radon. For a simple piece of equipment this may be feasible, but for complex equipment it can be difficult to get solvent in contact with all of the places where the radon film is attached. If the equipment is cleaned, typically, the solvent waste has sufficiently diluted the NORM content that special handling of the liquids is not required. If the equipment cannot be cleaned or is no longer needed, only two options remain — disposal at a perpetual care site (Envirocare or U.S. Ecology) or smelting overseas.

Soil and sludge are typically the largest volume NORM wastes, since extensive removal can be required to assure that all of the NORM contamination is extracted. If only a small volume of these wastes exist at a site, dilution and landspreading onsite may be an option. Likewise, downhole encapsulation may be possible if a well scheduled for plugging is available. Typically, however, the volume of waste would dictate use of offsite waste management, where options are still limited. Selection among the available options will depend on the volume of waste, its activity level, and the location of the waste relative to available offsite disposal sites, as well as cost. NOW sites, such as those operated by Campbell and Newpark, will take these wastes up to certain activity levels, but they must blend it with uncontaminated wastes or soil to reach approved levels of residual radioactivity for disposal. For high activity wastes, this can be quite expensive. For wastes above 2000 pCi/g, transportation to a perpetual care facility is the only available option.

Slurry injection shows substantial potential as a low cost disposal option for large volume wastes such as soil and sludge. Wastes may be slurried and injected at a commercially permitted disposal well (such as those operated by Newpark) or the operator may elect to permit a well for this purpose to dispose his/her own wastes. The latter choice would depend on the availability of a suitable disposal formation on company owned property, state regulations, the time and cost of obtaining necessary permits, the expected volume of company NORM wastes that could be disposed via slurry injection over the next few years, and the availability of grinding/mixing equipment for creating the slurry to inject. Given these factors, it seems likely that only a few large companies or those with substantial waste volumes may elect this route. Others are likely to use commercial disposal or one of the other options described above.

Management of NORM Scale in Tubulars



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