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SCRAP METAL MANAGEMENT ISSUES ASSOCIATED WITH NATURALLY OCCURRING RADIOACTIVE MATERIAL*

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ABSTRACT

Certain industrial processes sometimes generate waste by-products that contain naturally occurring radioactive material (NORM) at elevated concentrations. Some industries, including the water treatment, geothermal energy, and petroleum industries, generate scrap metal that may be contaminated with NORM wastes. Of these three industries, the petroleum industry probably generates the largest quantity of NORM-contaminated equipment, conservatively estimated at 170,000 tons per year.

Equipment may become contaminated when NORM-containing scale or sludge accumulates inside water-handling equipment. The primary radionuclides of concern in these NORM wastes are radium-226 and radium-228. NORM-contaminated equipment generated by the petroleum industry currently is managed several ways. Some equipment is routinely decontaminated for reuse; other equipment becomes scrap metal and may be disposed of by burial at a licensed landfill, encapsulation inside the wellbore of an abandoned well, or shipment overseas for smelting.

In view of the increased regulatory activities addressing NORM, the economic burden of managing NORM-contaminated wastes, including radioactive scrap metal, is likely to continue to grow. Efforts to develop a cost-effective strategy for managing radioactive scrap metal should focus on identifying the least expensive disposition options that provide adequate protection of human health and the environment. Specifically, efforts should focus on better characterizing the quantity of radioactive scrap available for recycle or reuse, the radioactivity concentration levels, and the potential risks associated with different disposal options.

INTRODUCTION

Several industries use processes that sometimes generate waste by-products containing naturally occurring radioactive material (NORM) at concentrations above background levels. For certain industries, including the water treatment, geothermal energy, and petroleum industries, NORM-contaminated wastes can accumulate inside pieces of equipment, thereby generating radioactively contaminated scrap metal when the equipment becomes obsolete. Proper management of this scrap metal is critical to provide adequate protection of human health and the environment.

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Isotopes of uranium-238 (U-238) and thorium-232 (Th-232) that are naturally present in subsurface formations are the primary sources of NORM in waste streams generated by the water treatment, geothermal energy, and petroleum industries.[1-3] In all three industries, the production of groundwater is the primary mechanism for conveying the radioactivity to the waste streams.** Uranium and thorium are highly insoluble and tend to remain in place in the subsurface formations. However, their radium daughter products are slightly soluble and may be brought to the surface in the produced groundwater, where they subsequently precipitate out in several different forms. In the petroleum industry, scales and sludges that accumulate in production equipment have the potential to contain elevated concentrations of radium. In contrast, the primary NORM-contaminated waste streams for the water treatment industry are sludge, spent ion-exchange resins, and spent activated charcoal.[3] For the geothermal energy industry, the primary NORM-contaminated waste streams are pipe scale and filter cake.[3]

With respect to the generation of radioactively contaminated scrap metal, the waste streams of greatest concern are NORM-contaminated scales and sludges that accumulate inside water-handling equipment. Scales are hard, insoluble sulfate deposits that form on the inside of pipes, tubulars, filters, pumps, wellheads, and other water-handling equipment. NORM-contaminated scales form when radium dissolved in the water coprecipitates with the barium, strontium, or calcium sulfate deposits. Sludge deposits consist of accumulations of solid materials, such as sand, rust, and other debris, that are removed from the water either by filtering or settling. The greatest volumes of sludge tend to accumulate in tanks and vessels where water is stored for an extended period. NORM in sludge typically is in the form of radium-containing silicates and carbonates.

CHARACTERIZATION OF NORM WASTES

The primary radionuclide of concern in NORM wastes generated by the water treatment, geothermal energy, and petroleum industries is radium-226 (Ra-226), which forms by the decay of U-238. Other radionuclides of concern include radium-228 (Ra-228), which decays from Th-232, and radon-222 (Rn-222), a daughter product of Ra-226.[1-3]

Available data indicate that total radium concentrations (i.e., Ra-226 plus Ra-228) in petroleum industry scales and sludges can vary from undetectable levels to extreme measurements of 410,000 picocuries per gram (pCi/g) in scale[3] and 700,000 pCi/g in sludge.[4] Although a considerable amount of data describing total radium concentrations has been collected by petroleum companies and state agencies, these data have not been aggregated to a national level, making it difficult to determine the statistical distribution of total radium concentrations in scales and sludges. The only national-level survey conducted to date,[5] sponsored by the American Petroleum Institute (API), measured external gamma exposures from contaminated equipment.

** Although the water treatment industry also treats surface water that may contain radium, this is considered to be a secondary source for NORM because radium-226 (Ra-226) concentrations in surface water typically range from 0.01 to 1 picocurie per liter (pCi/L), whereas Ra-226 in groundwater pumped from drinking water aquifers can be much higher, ranging from 0.5 to 25 pCi/L.[3]

The data from that survey cannot be used to derive statistically representative source term concentrations because (1) the survey did not provide adequate coverage of some geographic areas, (2) the survey was limited to those companies that responded, (3) statistically designed sampling schemes were not used, and (4) the survey is considered to be biased toward high concentrations because measurements were collected only from equipment expected (on the basis of previous survey results) to be contaminated with NORM.[5] In addition, the conversion from external gamma readings to radium concentration is heavily dependent on several highly variable factors (e.g., equipment geometry, shielding factors, internal distribution of radium).

Despite these limitations, the API survey data have been widely used to characterize the statistical distribution of radium concentrations in petroleum industry NORM. In particular, several studies have relied specifically on the API survey data collected in Louisiana, primarily because they represent the most complete set of data available.[3,6,7] On the basis of the Louisiana data, the average total radium concentrations are 480 pCi/g in scale and 75 pCi/g in sludge (Table 1).

Average concentrations of total radium in petroleum industry NORM scales and sludges are higher than average concentrations for water treatment sludges or geothermal energy scales (Table 1). According to an U.S. Environmental Protection Agency (EPA) report on diffuse NORM,[3] the average concentration of total radium in geothermal energy wastes is 211 pCi/g (on the basis of only seven samples). The EPA estimates the range of Ra-226 concentrations in water treatment sludges to be 4 to 8 pCi/g (no average concentration was calculated) on the basis of the typical range of Ra-226 concentrations in the influent water.[3]

Table 1: Radium Concentrations in Scales and Sludges

Industry	Concentration (pCi/g)	
	Scale	Sludge
Petroleum industry		
Average concentration of total radium	480	75
Geothermal energy industry		
Average concentration of total radium	211	n/a[a]
Water treatment industry		
Estimated range of radium-226 concentrations	n/a[a]	4 to 8

[a] n/a: not available
Source: Reference 3.

The total volume of NORM-contaminated equipment generated each year has not been determined. However, of the water treatment, geothermal energy, and petroleum industries, the latter probably generates the largest quantity. The petroleum industry is estimated to generate over 170,000 tons of NORM-contaminated scrap metal each year. This value was calculated by estimating the quantity of scrap equipment generated annually through well abandonment and assuming that 10% of that quantity would be contaminated with NORM. According to the API, the number of stripper wells abandoned annually between 1982 and 1992 ranged from a low of 9,000 wells to a high of 19,000 wells.[8] To include both stripper and non-stripper wells, it is assumed that 18,000 wells are abandoned annually. If a conservative average depth of 3,000 meters per well is assumed, each abandoned well would generate 96 tons of tubulars. The quantity of tubulars generated each year by well abandonments (18,000 wells × 96 tons per well) totals 1.728×10^6 tons. Because (1) most of the equipment likely to become scrap probably consists of tubulars and small items (e.g., filters, valves) that cannot be cleaned easily and (2) the calculation is based on conservative assumptions, the estimated annual quantity of tubulars is considered to approximate the annual quantity of scrap equipment. If 10% of that quantity is contaminated with NORM, the annual quantity of NORM-contaminated scrap equipment is estimated at 172,800 tons. The 10% estimate is a reasonable assumption given that the range of NORM-contaminated wells observed by API is 7-15%[8] and that the entire depth of a well is not likely to be contaminated with NORM.

REGULATORY FRAMEWORK

Currently, no federal regulations specifically address the handling and disposal of NORM. In the absence of federal regulations, some states have developed their own regulatory programs. To date, five states have promulgated NORM programs, and many others have drafted NORM regulations. In addition, the Conference of Radiation Control Program Directors, Inc. (CRCPD), an organization of representatives from state and local radiation control programs, has drafted recommended NORM regulations.[9] These recommended regulations, referred to as the Part N regulations, are intended to provide guidelines for states to use in developing their NORM regulatory programs.

The existing state regulatory programs establish standards for (1) the licensing of parties possessing, handling, or disposing of NORM; (2) the release of NORM-contaminated equipment and land; (3) worker protection; and (4) NORM disposal. These programs establish standards and licensing requirements for facilities that clean NORM-contaminated equipment. Although smelting standards are not included in the Part N regulations recommended by the CRCPD, two of the state programs authorize the smelting of NORM-contaminated equipment, provided the total radium concentration in the end product does not exceed specified limits. Part 46.10(a) of the Texas Regulations for Control of Radiation (TRCR)[10] states that a general licensee may dispose of NORM-contaminated scrap metal by smelting if the expected average concentration of NORM in the end products or melt by-products does not exceed 5 pCi/g total radium (or 30 pCi/g total radium if the radon emanation rate is less than 20 pCi per square meter per second). Part 46.10(c) establishes an acceptance limit that allows commercial smelting facilities to recycle equipment if the radiation level measured 18 inches from the equipment does not exceed 2 millirem per hour. Title 33, Part XV, Section 1412.D, of the Louisiana Administrative Code[11] also allows smelting of NORM-contaminated equipment if dilution of the NORM in the end products or melt by-products is sufficient to reduce the radium concentration to 5 pCi/g; however, Louisiana requires that this activity be authorized by a specific license.

The International Atomic Energy Agency (IAEA) is in the process of deriving recommended limits that could apply to the release of contaminated materials generated by either the nuclear energy industry or the U.S. Department of Energy.[12] The IAEA is proposing a clearance level of 0.3 becquerel per gram (i.e., 8 pCi/g) for Ra-226, Ra-228, Th-228, and lead-210; materials containing contamination with higher levels would not be available for unrestricted release. Although the IAEA recommendation does not address NORM-contaminated scrap metal, this proposed limit could establish a standard that regulatory agencies might choose to apply to the release of NORM-contaminated equipment as well.

CURRENT MANAGEMENT OPTIONS

In general, the effect of state-level NORM regulations has been to limit the number of management options available for NORM-contaminated wastes, including scrap metal, thereby driving up the cost of managing these wastes. One of the primary objectives of the NORM regulatory programs is to provide adequate protection of human health and the environment. As a result, state programs limit the conditions under which radioactively contaminated scrap metal can be reused, recycled, or disposed of. Several management options exist for NORM-contaminated equipment generated by the petroleum industry (Figure 1). While some pieces of NORM-contaminated equipment (e.g., piping, storage tanks) can be decontaminated and reused, other pieces become scrap metal because they either (1) cannot be easily cleaned (e.g., filters, pumps, tubing) or (2) are not suitable for reuse because of a potential integrity failure. Scrap equipment currently is disposed of by burial at a landfill licensed to accept NORM or low-level radioactive waste, encapsulation inside an abandoned well (provided the equipment is small enough to fit inside the wellbore), or shipment overseas for smelting.

Risk reduction and economics are key issues that should be evaluated when selecting the most appropriate management option for NORM-contaminated equipment. Because a variety of factors (e.g., quantity of contaminated scrap metal, location of the scrap with respect to the decontamination or disposal facility, relative reduction in risk associated with each option) determine risk reduction and cost, cost/benefit analyses may be needed on a case-by-case basis to determine the most appropriate management option. Each of the current management options identified above has drawbacks that should be considered. For example, in some cases, decontamination and reuse of the equipment can be a cost-saving measure; however, the cleaning process can be expensive because (1) it should be performed at a licensed facility that provides for worker safety and (2) it generates a radioactive waste stream (i.e., the recovered NORM-contaminated scale or sludge) that also must be managed appropriately. Most management options for NORM-contaminated scale and sludge are costly. The cost of decontamination and subsequent disposal of the recovered waste may offset any savings realized by reusing the equipment. Likewise, the cost of disposing of radioactively contaminated scrap metal in a licensed landfill can be prohibitively high. In addition, it is possible that the large inventory of radioactively contaminated scrap metal could rapidly overwhelm the existing national capacity for landfilling these wastes. Encapsulation inside abandoned wells is a realistic option only for small pieces of equipment (e.g., filters, screen, tubing strings) or larger items that have been cut up. In addition, it is uncertain if the number of suitable wellbores available for such use is adequate to handle the inventory of contaminated scrap metal. Shipment of radioactively contaminated scrap metal overseas for smelting currently is a viable option only for the major oil companies that generate large quantities of scrap metal and can arrange contracts with foreign countries. Even for the large companies, however, shipping the scrap overseas is a controversial disposal practice because of concerns that the laws of foreign countries are too lax to provide adequate protection for workers and the general public.[13,14]

Because of the relatively high cost of disposing of NORM-contaminated equipment, many petroleum companies currently are storing their contaminated scrap metal until other, less expensive disposal options can be identified. One potential alternative for disposing of NORM-contaminated scrap metal is smelting at domestic facilities. Recent studies indicate that most of the radioactivity partitions itself into the slag[15] and that potential radiological doses to the general public from the end-product metal would be negligible.[7] Potential radiological doses to the workers could be controlled to negligible levels through control of the throughput of NORM-contaminated scrap.[7] However, at this time, the U.S. scrap metal recycling industry does not accept NORM-contaminated scrap metal. Commercial facilities are reluctant to smelt NORM-contaminated scrap in part because no federal standards currently exist that would allow the NORM-contaminated scrap to be diluted with larger quantities of clean scrap for eventual smelting and subsequent reuse of the metal.[13]

CONCLUSIONS

In view of the increased regulatory activities addressing NORM, the economic burden of managing NORM-contaminated wastes, including radioactive scrap metal, is likely to continue to grow. Efforts to develop a cost-effective strategy for managing radioactive scrap metal should focus on identifying the least expensive disposition options that provide adequate protection of human health and the environment. Specifically, efforts should focus on better characterizing the quantity available for recycle or reuse, the radioactivity concentration levels, and the potential risks associated with different disposal options.

REFERENCES

1. Smith, A.L., 1987, "Radioactive-Scale Formation," *Journal of Petroleum Technology* 39(6):697-706.

2. Baird, R.D. et al., 1990, *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*, report RAE-8837/2-2, Rogers and Associates Engineering Corp., Salt Lake City, Utah.

3. U.S. Environmental Protection Agency, 1993, *DRAFT Diffuse NORM - Waste Characterization and Preliminary Risk Assessment*, Office of Radiation and Indoor Air, Washington, D.C.

4. Fisher, J.B., and M. Hammond, 1994, "Characterization of NORM Vessel Solids," *Environmental Issues and Solutions in Petroleum Exploration, Production and Refining*, Proc. International Petroleum Environmental Conf., University of Tulsa and PennWell Books, Houston, Texas.

5. Otto, G.H., 1989, *A National Survey on Naturally Occurring Radioactive Materials (NORM) in Petroleum Producing and Gas Processing Facilities*, prepared for American Petroleum Institute, Dallas, Texas.

6. U.S. Environmental Protection Agency, 1993, *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana - Peer Review Draft*, Office of Radiation and Indoor Air, Washington, D.C.

7. Smith, K.P. et al., 1995, "Radiological Dose Assessment Related to Management of Naturally Occurring Radioactive Materials Generated by the Petroleum Industry," paper SPE 29712, *Proceedings of the SPE/EPA Exploration & Production Environmental Conference 95*, Society of Petroleum Engineers, Inc. and U.S. Environmental Protection Agency, Houston, Texas, pp. 231-240.

8. Loudermilk, M., 1994, personal communication from Loudermilk (Exploration and Production Department, American Petroleum Institute, Dallas, Texas), to K.P. Smith (Argonne National Laboratory, Lakewood, Colo.), Dec. 7.

9. Conference of Radiation Control Program Directors, Inc., 1994, *Part N Regulation and Licensing of Naturally Occurring Radioactive Materials (NORM)*, SR-5 Committee, Frankfort, Ky.

10. Texas Regulations for Control of Radiation, "Licensing of Naturally Occurring Radioactive Material (NORM)," TRCR Part 46, Austin, Texas.

11. Louisiana Administrative Code, 1995, "Regulation and Licensing of Naturally Occurring Radioactive Materials (NORM)," LAC 33:XV, Chapter 14, Baton Rouge, La.

12. IAEA, 1994, *Clearance Levels for Radionuclides in Solid Materials: Application of Exemption Principles*, IAEA Safety Series No. 111.G-1-5, Draft, International Atomic Energy Agency, Vienna, Austria.

13. Lubenau, J.O., and J.G. Yusko, 1995, "Radioactive Materials in Recycled Metals," *Health Physics* 68(4):440-451.

14. Shinkle, P., 1994, "China Gets Radioactive Scrap Equipment," *The Advocate*, Baton Rouge, La., April 4.

15. Dehmel, J.C. et al., 1992, *Scrap Metal Recycling of NORM Contaminated Petroleum Equipment*, prepared for Petroleum Environmental Research Forum, Ponca City, Okla.

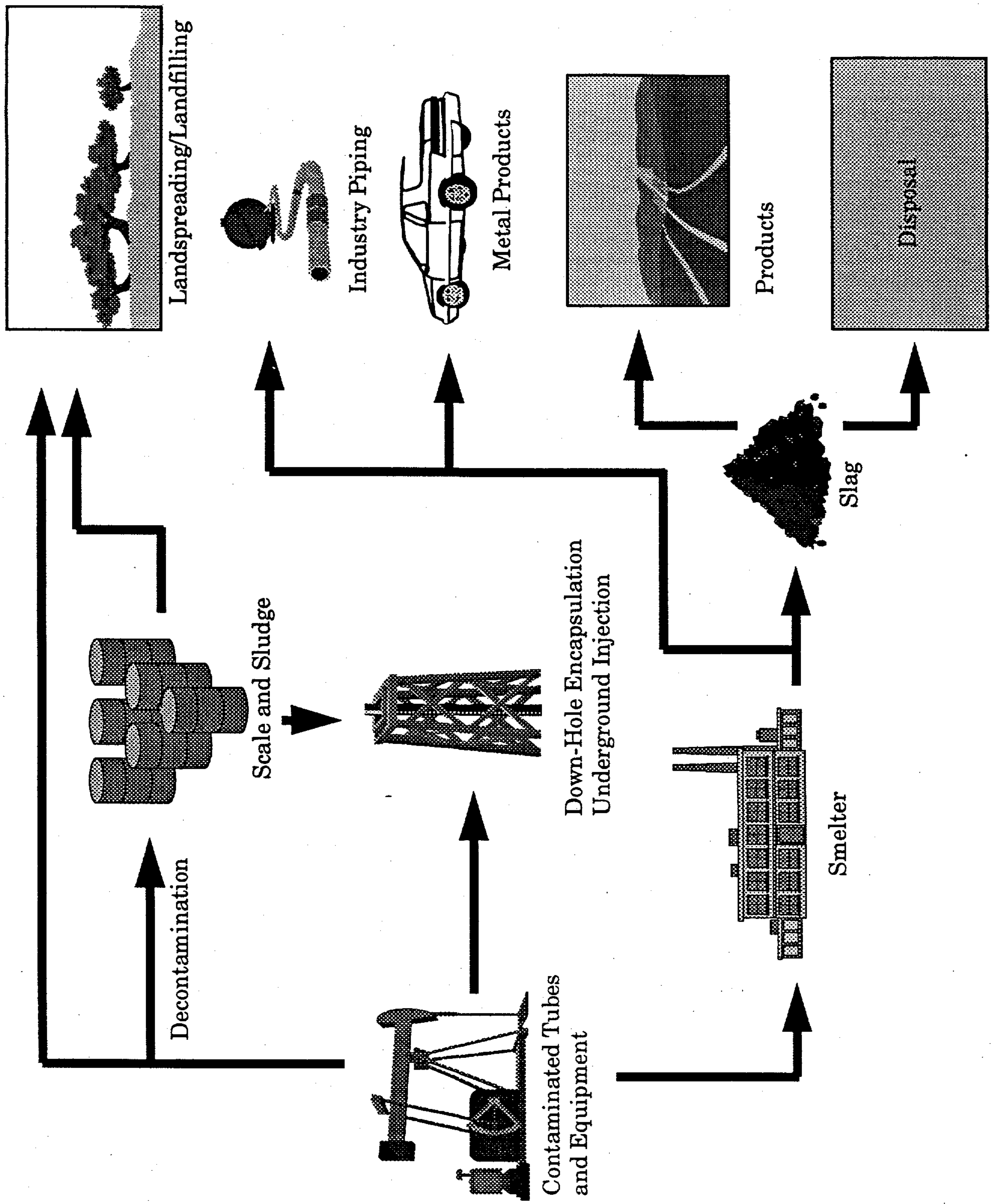

Figure 1: NORM Disposal and Management Alternatives