

NORM Management in the Oil & Gas Industry

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Abstract. It has been established that Naturally Occurring Radioactive Materials (NORM) may accumulate at various locations along the oil/gas production process. Components such as wellheads, separation vessels, pumps, and other processing equipment can become NORM contaminated, and NORM can accumulate in the form of sludge, scale, scrapings and other waste media. This can create a potential radiation hazard to workers, general public and the environment if certain controls are not established. Saudi Aramco has developed NORM management guidelines and is implementing a comprehensive strategy to address all aspects of NORM management which aim towards enhancing:

- NORM monitoring
- Control of NORM contaminated equipment
- Control over NORM waste handling and disposal
- Workers protection, awareness, and training

The benefits of shared knowledge, best practice and, experience across the oil & gas industry are seen as key to the establishment of common guidance. This paper outlines Saudi Aramco's experience in the development of a NORM management strategy and its goals of establishing common guidance throughout the oil and gas industry.

1. Introduction

Naturally Occurring Radioactive Material (NORM) is a by-product waste of oil production and its presence in pipelines, plant and machinery may cause restriction of operability and potential radiological health hazards [1]. Workers who are required to work with plant or equipment which is NORM contaminated have potential for external radiation exposure from closed systems during normal operations and internal exposure if no controls are established during shutdowns and periods where systems are opened [2]. Equipment contaminated with NORM cannot be released for sale or disposal without being decontaminated and verified free of NORM contamination. Waste material contaminated with enhanced levels of NORM requires to be disposed off in a controlled manner to ensure it does not provide an unacceptable risk to the environment and the general public [3]. As the hazard of NORM in the oil & gas industry became internationally recognized, Saudi Aramco initiated a program to identify the extent, form and level of NORM contamination associated with their operations. Once positive indications that enhanced levels of NORM existed the company was faced with the problem of ensuring that its workforce, the general public and the environment were protected from the associated hazards.

2. Saudi Aramco

Saudi Aramco is the fully integrated, global petroleum enterprise of the Kingdom of Saudi Arabia. The company has operations in exploration, producing, refining, marketing and international shipping. Building on a legacy that dates back more than 75 years, Saudi Aramco today leads the world in crude oil production and exports, is the top exporter of natural gas liquids and is a major natural gas producer [4]. The company has discovered and is responsible for, about one-quarter of the world's proven conventional oil reserves. Since it first found crude oil in commercial quantities in Saudi Arabia's Eastern province in 1938, the company has discovered about 90 oil and gas fields throughout the Kingdom and its offshore waters. More than one-fourth of the discoveries have been made since 1989. Saudi Aramco's maximum sustainable crude oil production capacity is 10.8 million barrels per day [4]. The company's master gas system is one of the largest gas gathering, processing and distribution networks of its kind in the world. Gas used as both fuel and feedstock is a major factor in the country's diversification and economic development activities [4].

3. NORM Identification

A team from Saudi Aramco's Environmental Protection Department (EPD) initiated (2001) a surveillance program to ascertain the level of NORM associated with Saudi Aramco's operations. The initial surveillance program was random, it centered on areas where it was thought that there was potential for NORM to exist. It was driven by the thirst for knowledge, rather than operational control. The surveillance involved direct monitoring of equipment using hand-held alpha, beta and gamma detectors and the collection of samples for laboratory analysis. The radiation detectors used were Sodium Iodide (NaI) for gamma radiation, and uncompensated Geiger-Muller tubes (pancake probes) for alpha/beta detection. Laboratory analysis of the samples provided results of total activity for the sample and initially no isotopic identification was provided. Positive indications of NORM being present in Saudi Aramco operations were found.

4. NORM Regulations & Guidance

Saudi Arabia has no national regulations specific to NORM, However, there is a General Radiation Protection regulations issued in 1997. Saudi Aramco has surveyed various international NORM regulations [5-10], guidance [11-13]and standards [14], and developed a practical NORM strategy to address the various aspects of NORM management. The development process included significant interaction with many oil & gas company experts, and researchers. The review indicated a wide range of action levels and limits, some of which were risk based and others specifying quantities. The review led Saudi Aramco to establish its levels at which controls required to be established to protect workers, the public and the environment. These levels were detailed in an internal procedure [15] which had the aim of managing all operations with NORM. The levels are considered best practice based upon prevailing guidance and practices throughout the oil & gas industry. Saudi Aramco limits for NORM are as follows:

- Materials and waste media such as sludge/scale containing NORM at levels below those listed in Table 1 shall be exempted.
- Soil shall not have a Ra-226 contamination above 0.185 Bq per gram (5 pCi per gram).
- Soil shall not have a U-238 contamination above 3.3 Bq per gram (90 pCi per gram).
- Equipment, vessels, and clothing shall be considered NORM contaminated if internal or external surface contamination measures double the radiation background level.

Table 1: Saudi Aramco NORM Exemption levels

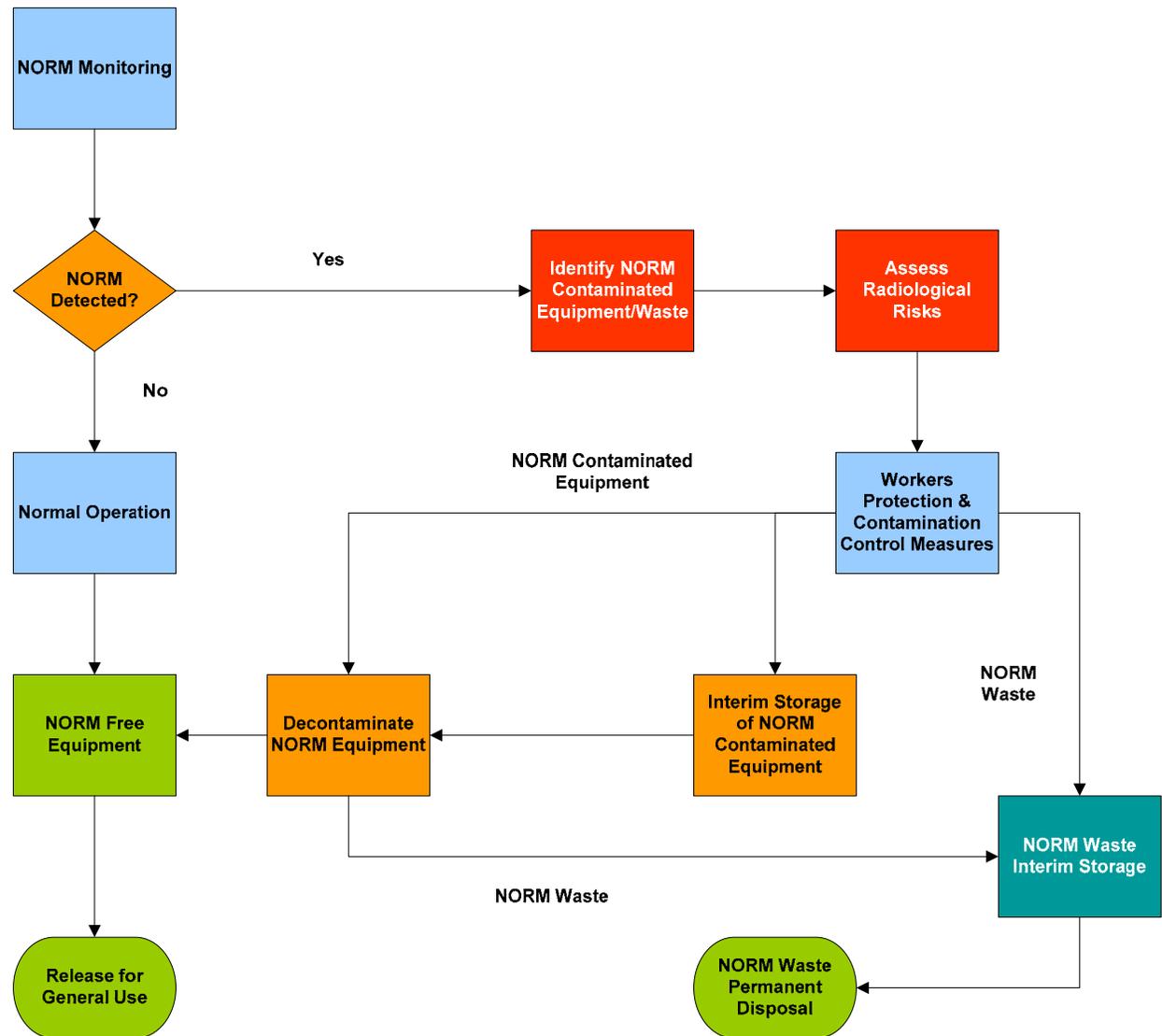
Radionuclide	Exemption Level (Bq/g)	Exemption Level (pCi/g)
Ra-226	1.1	30
Ra-228	1.1	30
Pb-210	0.2	5
Po-210	0.2	5
U-238	5.5	150
Uranium (Nat)	3.0	80

5. NORM Management Process Cycle

The positive indication of NORM associated with operations required a solution in the form of a management process to control it. The process required to be sold to operational management and as such needed to have clear benefits, be easily implemented and be cost-effective. The benefits were the provision of protection for their workers, communities and the environment. This was achieved by communication with operators to ensure that procedures and guidance fitted with their operations taking into consideration the working environment and work to be done. To that end operators felt involved in the process as it was tailored to their requirements. Cooperation and inclusion rather than imposition, provided a means whereby operators bought in to the process. Although no direct cost

benefit analysis has been completed costs associated are in line with the control and management of other occupational hazards. Also potential future litigation against the company if it took no action to manage a hazard with known causes and effects may be significant. The following process cycle (**Figure 1**) was established as the optimum means by which control can be established in all areas of operation.

Figure 1: Saudi Aramco NORM Management Process Cycle



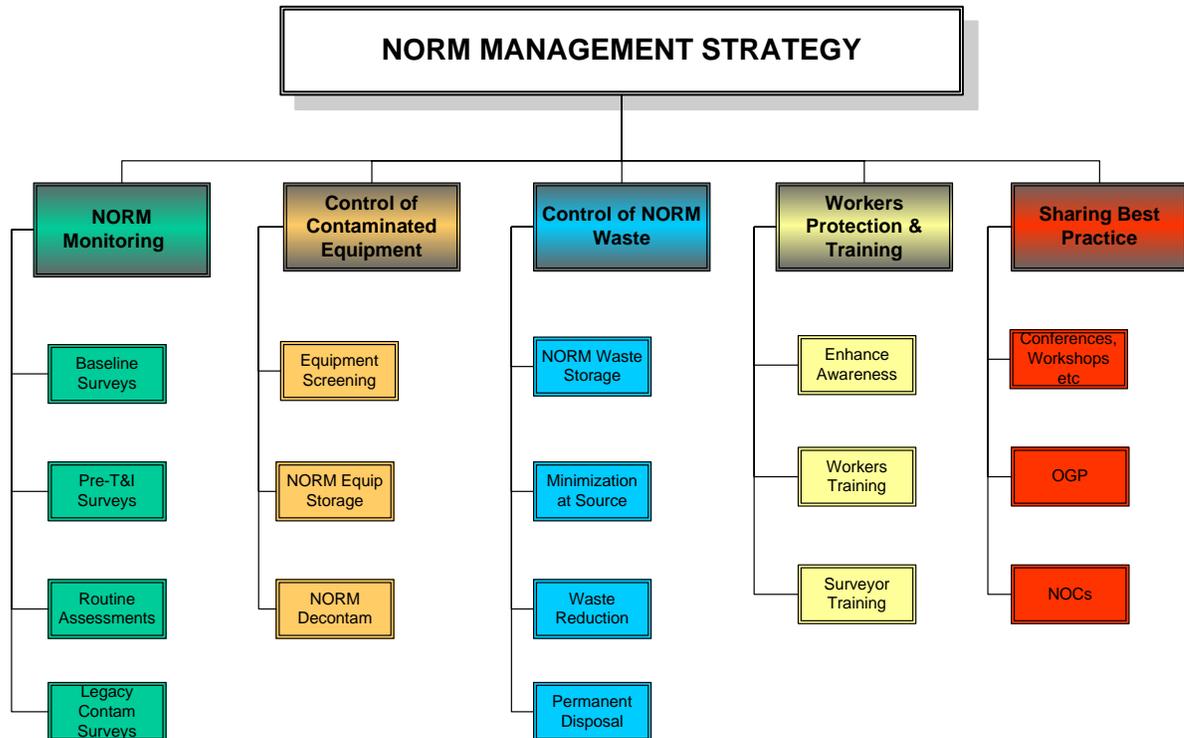
The NORM Management Process Cycle required a strategy to be implemented to ensure that all components of the process cycle could be adequately completed.

6. Saudi Aramco NORM Management Strategy

The NORM management strategy (**Figure 2**) contains five key elements, namely;

- NORM monitoring
- Safe management of NORM contaminated equipment
- Control of NORM waste
- Workers protection and training
- Sharing Best Practice

Figure 2: Saudi Aramco NORM Management Strategy



The strategy formed the focus of attention to allow activities to be planned and executed utilizing the available resource to maximum effect. The implementation of NORM strategy required significant management support from all sections of the organization. Action is required to commence on many fronts over a relatively short period of time. Initial reactions across the organization varied considerably so effort was placed on ensuring a common message was portrayed with the emphasis on assisting proponents in problem solving, rather than imposing restrictions and constraints on their operations.

6.1 NORM Monitoring

NORM monitoring is composed of four main components namely:

- Baseline surveys
- Pre Test and Inspection(T&I) surveys
- Operational assessments
- Legacy contamination surveys

6.1.1 Baseline Surveys:

The objective is to establish a baseline of the spread and level of NORM accumulation in Saudi Aramco facilities. These information are essential in determining which category of workers need protection guidelines, and type of contamination control procedure. Baseline surveys also yield important information about NORM waste streams in Saudi Aramco which is essential input toward developing disposal solutions.

6.1.2 Pre T&I Surveys:

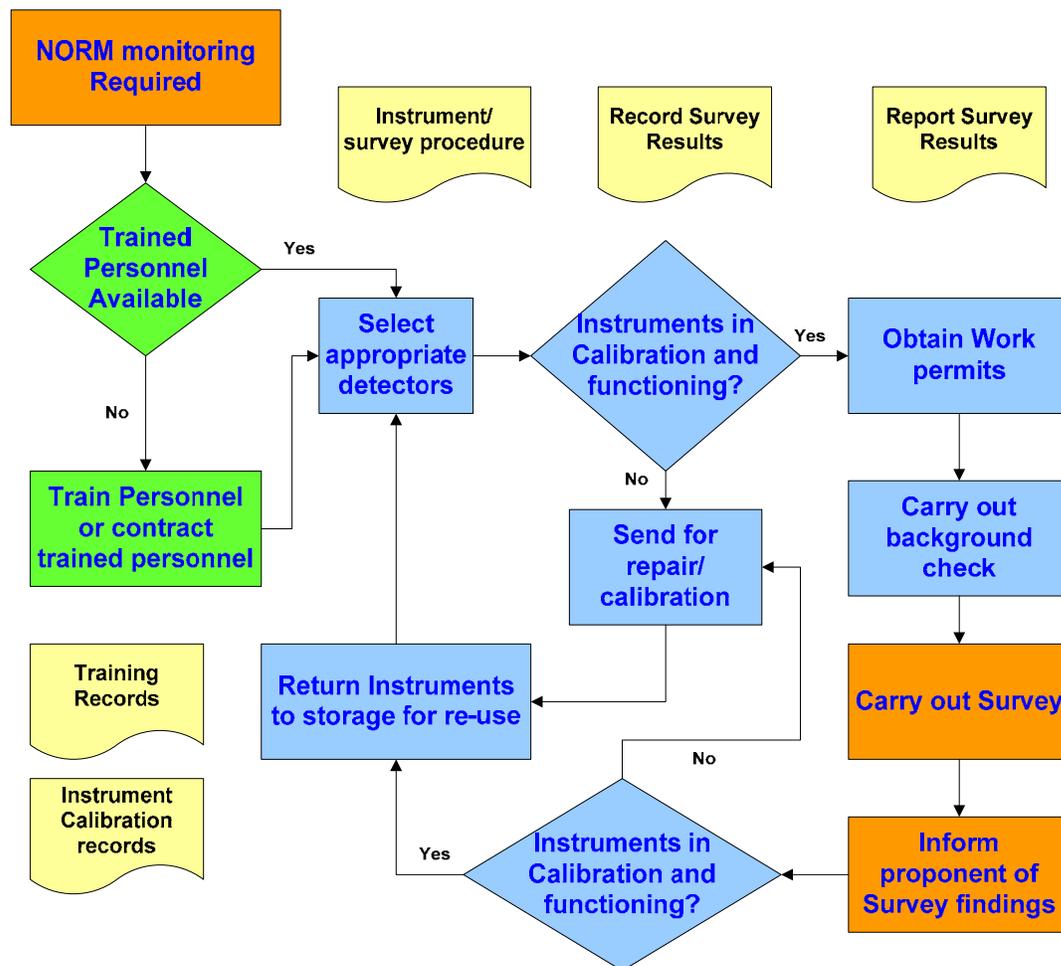
The objective is to determine the locations of NORM accumulations in facilities where NORM contamination is suspected, such as Gas/Oil Separation Plants (GOSPs), 2-4 weeks before each T&I. If NORM presence is detected proper procedure is implemented to protect workers, minimizes

workplace contamination during T&I and control handling and disposal of NORM waste. EPD's objective is that a number of employees in each facility, such as environmental coordinators, are trained to conduct Pre T&I NORM surveys or facilities contract this service.

6.1.3 Operational (Routine) NORM Assessments:

The objective is to enable field organizations to identify NORM contamination promptly during routine operational scenarios through training of selected number of employees to conduct operational NORM assessments. In operating facilities situations arise where workers might need to conduct intrusive work, such as clean up or maintenance, on a potentially NORM contaminated equipment or entry into potentially contaminated vessels. In such situations, field personnel should be capable of conducting NORM assessment using portable and easy to use instruments to identify whether there is NORM contamination (**Figure 3**).

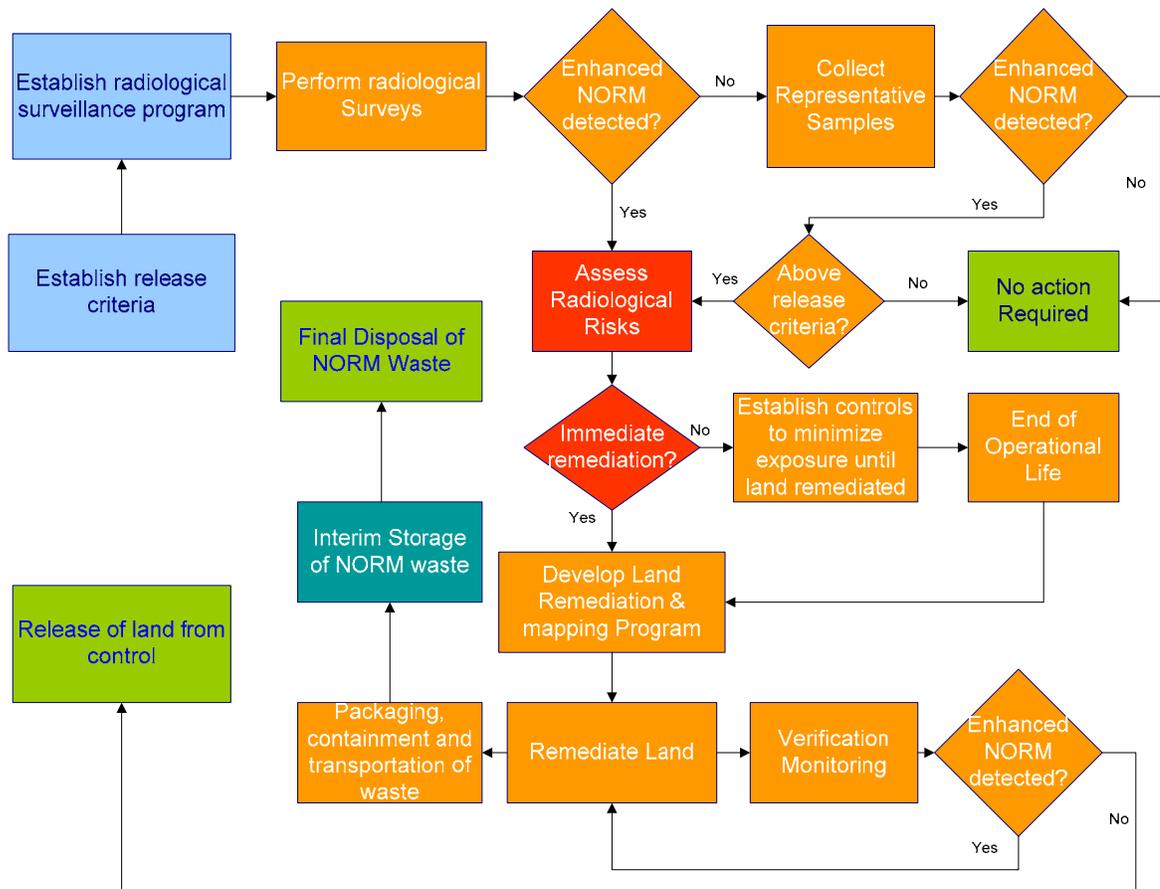
Figure 3: Schematic of NORM survey requirements



6.1.4 Legacy Contamination Surveys:

The objective is to identify and remediate areas of legacy NORM contamination before such areas are decommissioned or released for general purpose using competent contractors under EPD guidance (**Figure 4**). Legacy contamination is a contamination resulting from operations prior to implementing NORM management strategy. Areas with potential legacy NORM contamination include but not limited to land farms, evaporation ponds, disposal pits and other areas where NORM contamination was potentially accumulating. Remediation of these areas may be required [16].

Figure 4: Remediation of NORM contaminated land



6.2 Control of NORM Contaminated Equipment

Control of NORM contaminated equipment is composed of three stages namely (Figure 5):

- Screening of Equipment
- Storage of NORM Contaminated Equipment
- Decontamination of NORM Contaminated Equipment

6.2.1 Screening of Equipment for NORM Contamination:

The objective is to establish and implement simple and effective procedure to identify and segregate NORM contaminated equipment using portable, durable and user friendly radiation detection devices. EPD provide the necessary training to conduct the NORM screening or training could be conducted by competent contractors approved by EPD. In operating organizations this objective is covered through Pre T&I NORM surveys and operational (routine) NORM assessment

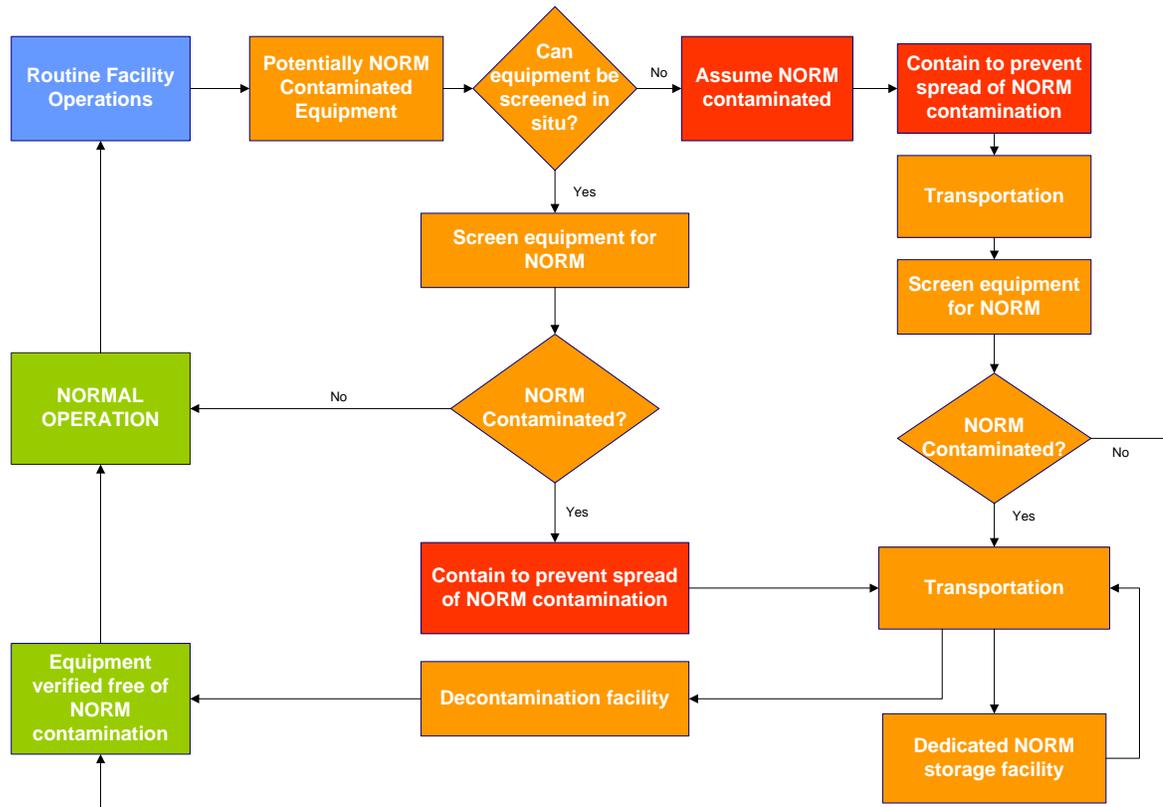
6.2.2 Storage of NORM Contaminated Equipment:

The objective is to prevent NORM contaminated equipment from being sent to contractors for maintenance/repair, disposed off or sold to public, hence becoming a source of radiation hazard by isolating such equipment and storing it in a designated area.

6.2.3 Decontamination of NORM Contaminated Equipment:

The objective is to decontaminate NORM contaminated equipment before return to operation, disposal or release for sale to public. Decontamination of NORM contaminated equipment must be conducted in specially designed facilities. Such facilities are designed in a manner that prevents radiological exposure of the decontamination workers, prevents contamination of work place and the resulted NORM waste is adequately segregated and disposed off in accordance with approved disposal methods.

Figure 5: Control of NORM contaminated Equipment



6.3 Control of NORM Waste

This element of the NORM management strategy is composed of four components (**Figure 6**):

- Storage of NORM waste
- Minimization of NORM at the Source
- NORM Waste Volume Reduction
- Permanent Disposal of NORM Waste

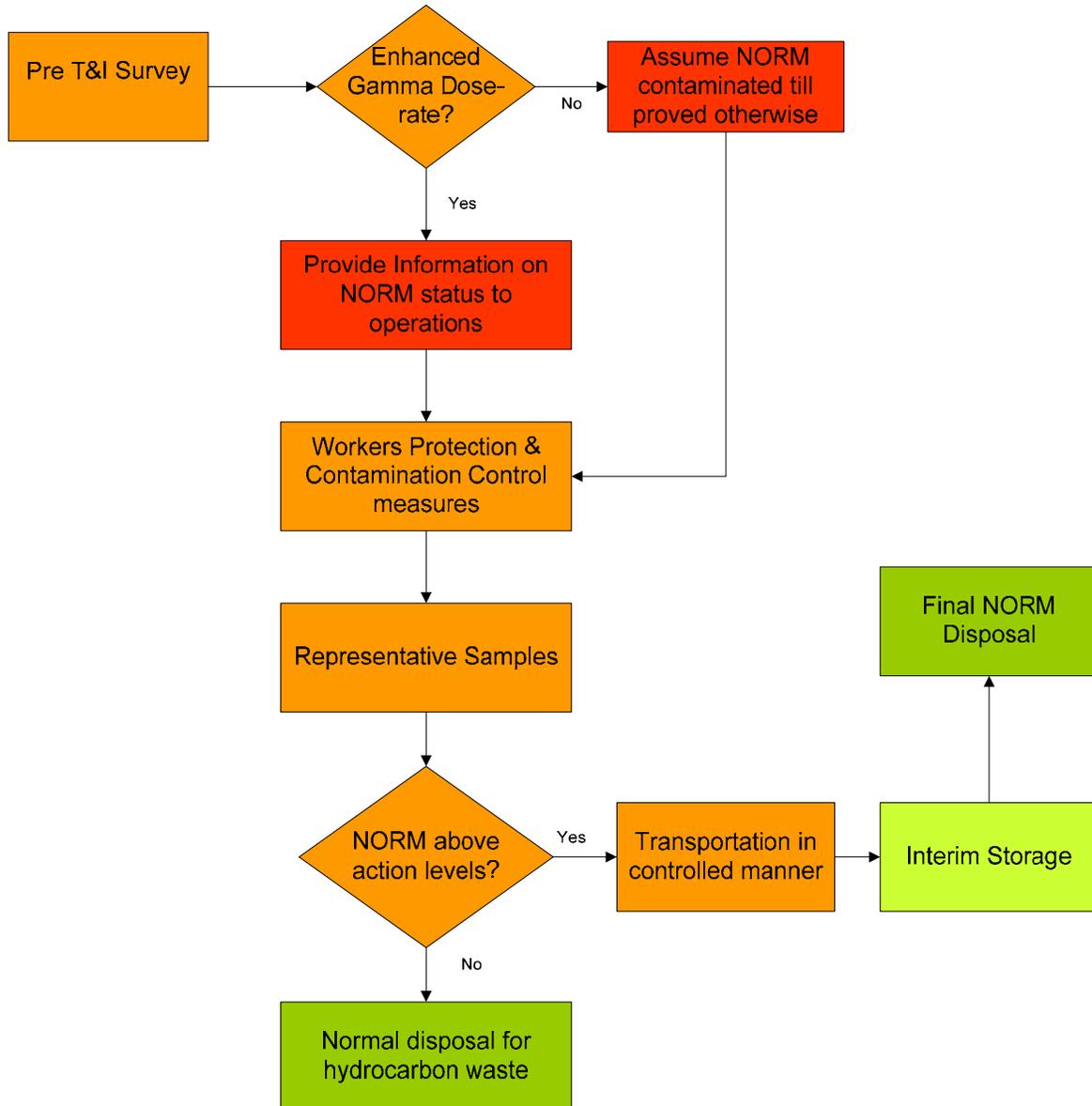
6.3.1 Storage of NORM Waste:

There are two objectives in this regard, short term storage solutions and interim storage process.

- *Temporary Storage Solutions*, where the objective is to prevent uncontrolled and improper disposal of NORM waste through providing quick, effective and easy to implement solutions to operating facility to control the NORM waste on a temporary basis. Temporary storage in Saudi Aramco is provided in 200litre drums (metal or heavy duty plastic)
- *Interim Storage of NORM Waste*, where the interim storage will be an integral stage of the NORM waste disposal process where interim storage facility will receive NORM waste generated by various operating facilities and could be accumulated over a period of time depending on the waste generation rate. It is planned that large vessels previously used in

GOSPs (i.e. obsolete test traps) will be used to store NORM waste. These will provide greater engineering integrity and containment than individual drums.

Figure 6: Control of NORM waste during shutdown operations



6.3.2 Minimization of NORM at the Source:

The objective is to identify practical and cost effective means to minimize or prevent uranium accumulation in seawater injection (SWI) pipes/equipment some examples for consideration include:

- The use of continuous biocide treatment for Sulfate Reducing Bacteria (SRB)
- Removing sulfate from the seawater injection system, hence depriving SRB of its “food”.
- Investigating methods of reducing or eliminating SRB through bio-competitive exclusion i.e. enhancing the growth of bacterial organisms that could eliminate SRB.
- The interior surfaces of any replacement or additions to the system should be FBE coated.

This particular type of NORM is attributed mainly to metabolic activity of SRB which flourishes in the anaerobic environment in the deoxygenated seawater in the SWI pipes [17]. The SRB plays a pivotal role in accumulating uranium in SWI pipes/equipment.

6.3.3 NORM Waste Volume Reduction:

The objective is to reduce the volume of NORM contaminated waste through removal of the non NORM constituents, by investigating new hydrocarbon separation or removal technologies such as the Petrozyme Bioreactors Technology [18]. This stage could also be part of the interim storage stage.

6.3.4 Permanent Disposal of NORM Waste:

The objective is to establish safe, practical and cost effective permanent disposal protocol for NORM waste which provides adequate protection to human health and the environment. The permanent disposal protocol should be designed to prevent contamination of natural resources such as underground water or contaminate soil that could become in the far future part of residential or agricultural areas although presently it may be remote or uninhabited. Saudi Aramco has completed a detailed assessment of NORM disposal options for its operations in Saudi Arabia. Six methods of disposal used elsewhere in the industry were considered, these included:

- Landfill Disposal
- Underground Injection
- Land spreading
- Salt Cavern Disposal
- Offshore Discharge
- Wetlands Disposal

These were preliminary ranked against a selection criteria which considered risk, technical feasibility, cost and general acceptance. From this initial ranking two options were carried forward for detailed risk and cost analysis, these were:

- Landfill Disposal
- Underground injection

Whilst both of these provided acceptable means of disposal the optimum option in terms of both risk and cost was established to be Underground Injection. The process of underground injection to be utilized is slurry fracture injection [19].

6.4 Workers Protection and Training

6.4.1 Workers Protection:

In line with Saudi Aramco policy, the highest priority in the NORM strategy is to protect workers through [20]:

- Rapid dissemination of workers protection guidelines even if NORM surveys are not yet conducted by adopting the conservative approach of implementing workers protection procedure if NORM contamination is suspected.
- Enhancing workers' awareness through holding NORM awareness sessions
- Provision of training on workers' protection measures and contamination control to workers who need to deal directly with NORM contamination such as cleanup of vessels containing NORM contaminated waste.

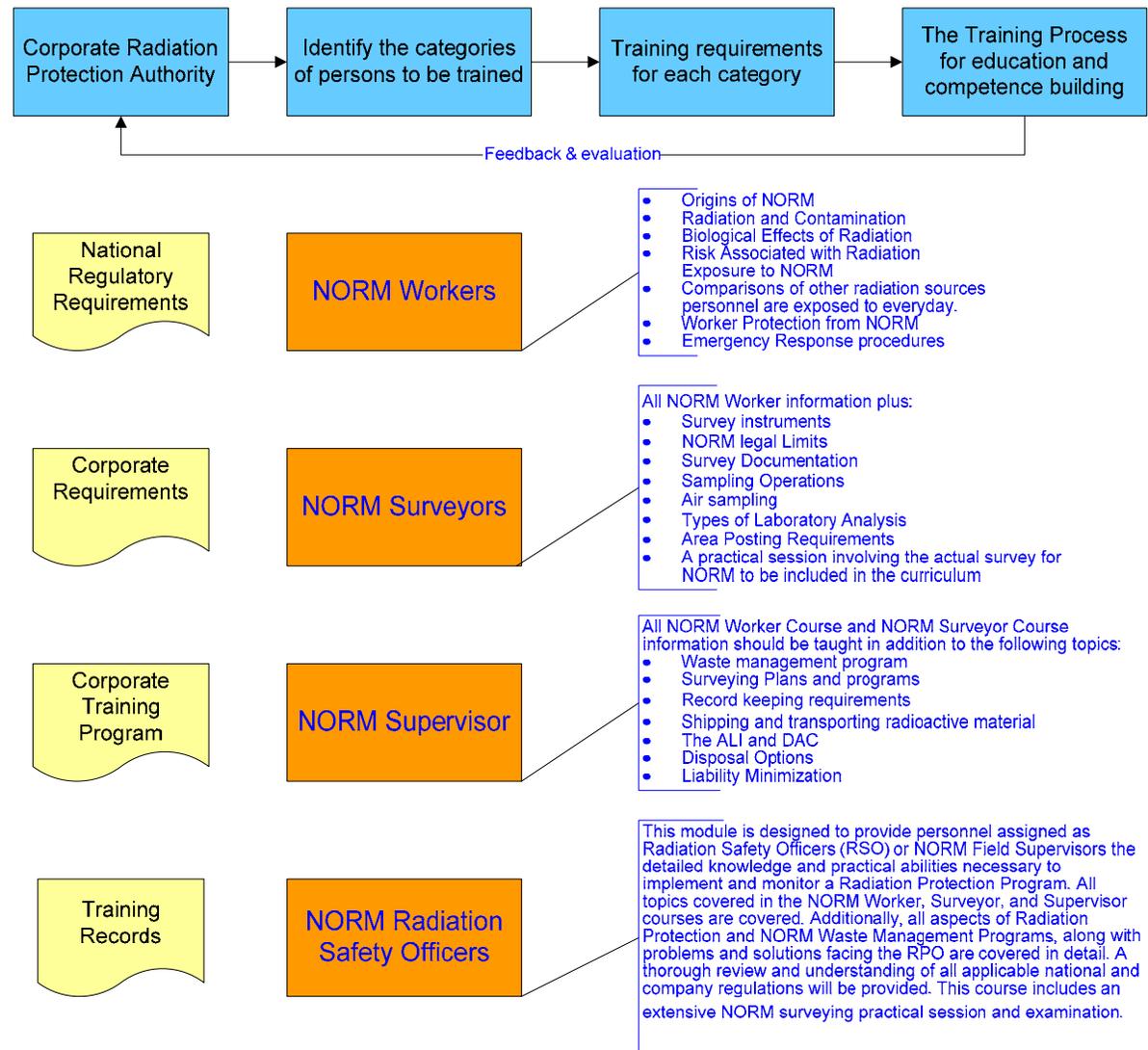
6.4.2 Training:

The objective is to train selected employees in facilities with potential NORM contamination to perform operational NORM assessments and Pre T&I NORM surveys. Four training courses have

been developed by EPD and are coordinated by Professional Engineering Development Division. The courses are (Figure 7):

- NORM (Naturally Occurring Radioactive Material) Workers Course
- NORM (Naturally Occurring Radioactive Material) Surveyors Course
- NORM (Naturally Occurring Radioactive Material) Supervisors Course
- NORM (Naturally Occurring Radioactive Material) Radiation Safety Officers Course

Figure 7: Training development process and core knowledge topics



6.5 Sharing Best Practice & Experience

An integral part of the NORM Management strategy is the interaction with other National and International Oil Companies, Oil & Gas Service Industry members and Industry associations working in the field of NORM management. Shared experience of a common problem can provide benefits to all concerned. Saudi Aramco actively participates in conferences, workshops and symposia and is involved in the development of generic guidance to National oil companies and International Oil & Gas association members.

7. Conclusion

Whilst researching NORM management issues to establish its NORM management strategy Saudi Aramco became aware of inconsistencies in the way NORM is managed and controlled throughout the industry and across the World. A common set of guidance which is flexible enough to be adaptable to legislation in different sovereign nations was seen as an achievable goal. This will provide users with continuity of management approach throughout the industry. It will also prevent others from having to re-invent the wheel, as an already proven approach to NORM management will be available to them.

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