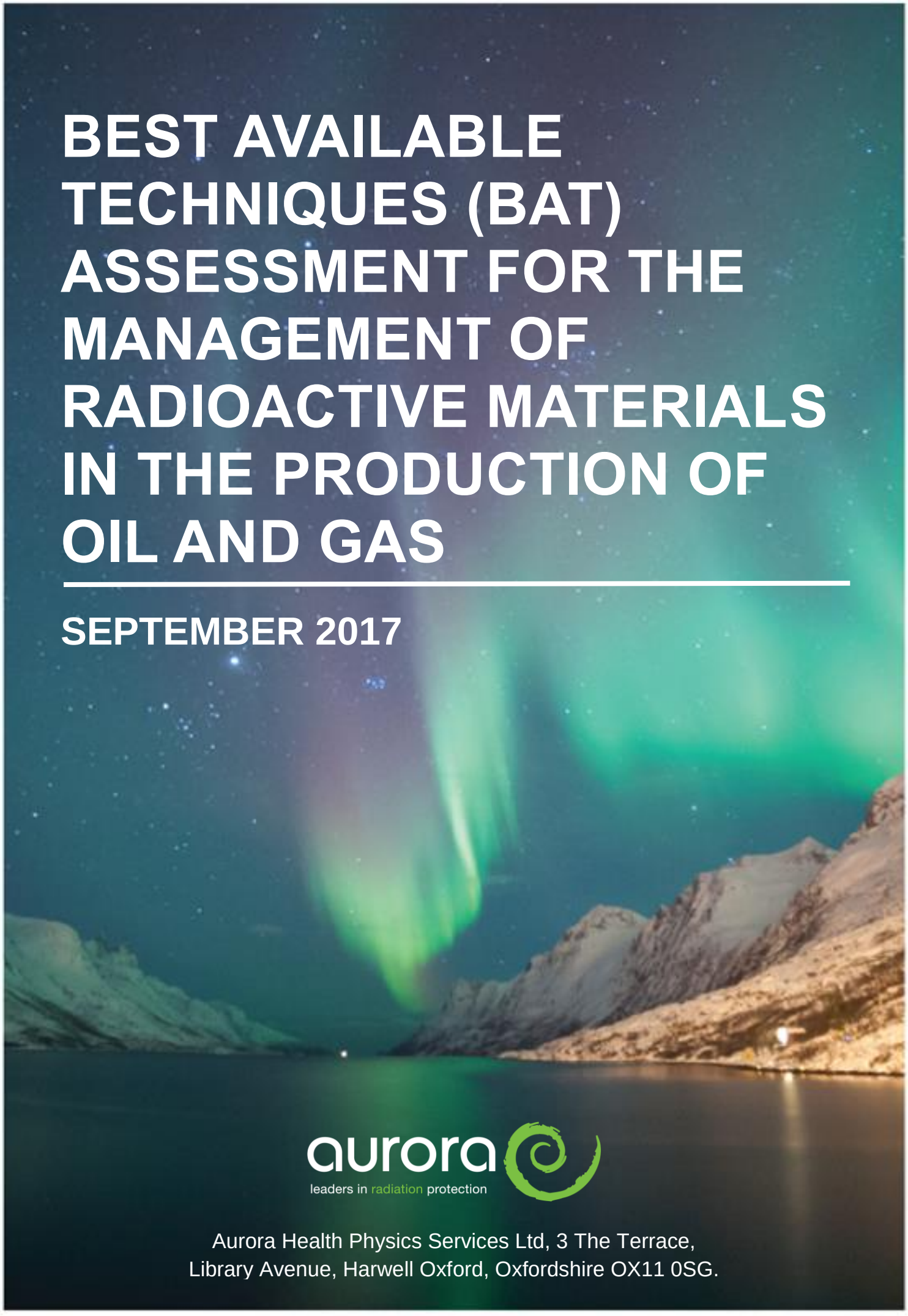
BEST AVAILABLE TECHNIQUES (BAT) ASSESSMENT FOR THE MANAGEMENT OF RADIOACTIVE MATERIALS IN THE PRODUCTION OF OIL AND GAS

SEPTEMBER 2017



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	Name	Position	Date	Signature
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Contents

1 Introduction

This document considers the application of Best Available Techniques (BAT) in relation to the accumulation of enhanced concentrations of Naturally Occurring Radioactive Materials (NORM) from operations as applied by IGas Energy plc Group Companies during onshore oil and gas exploration. BAT, as set out in this document, will be applied to each site where a Permit is required as appropriate to the NORM wastes relevant to the site under consideration.

The document should be read in conjunction with IGas Energy plc Group Companies applications for a Permit under the Environmental Permitting (England and Wales) Regulations 2016 (EPR16)[1] and used as a component of the larger assessment used for achieving compliance with the requirements of the Industrial Emissions Directive 2010.

2 Aims of IGas

IGas Energy plc Group (the Company)(IGas) undertake oil and gas extraction and exploration for new hydrocarbon deposits on the UK mainland. To deliver these undertakings, Island Gas is required to apply for and implement the requirement of any Permits issued under the Environmental Permitting (England and Wales) Regulations 2016 (EPR16).

The Company will endeavour to protect the environment and, as part of the Permit application process, will identify the potential waste arisings from its undertakings and identify how these will be managed through the use of Best Available Techniques (BAT).

In carrying out its undertakings, the Company will work in full compliance with the conditions and limitations set out in any Permit issued by the Environment Agency under EPR2016. The Company will also comply with the requirements of the extant issue of the Ionising Radiations Regulations (IRR) and will carry out its work in such a manner as to ensure that any exposures to personnel are kept As Low As Reasonably Practicable (ALARP).

The Company aim to apply BAT as a method of minimising the activity of any naturally occurring radioactive material residing in produced fluids or extractive wastes during oil and gas extraction and production in so far as is reasonably practicable using current knowledge and technology.

The Company will aim to carry out activities in a manner that minimises waste production (volumes and mass) and will dispose of radioactive wastes arising in a manner which minimises their environmental impact.

3 Radioactive Wastes in the Production of Oil and Gas

3.1 Naturally Occurring Radioactive Material (NORM)

Naturally Occurring Radioactive Materials are present in the Earth's crust as a series of radioactive elements with radioactive daughter products (radionuclides) created through radioactive decay of these elements. NORM wastes arise when these radioactive materials are concentrated through industrial activities, for example oil and gas extraction and recovery. NORM wastes are distinct from anthropogenic radioactive wastes, which arise because of work activities that deliberately process and use these materials for their radioactive, fissile or fertile properties. NORM wastes are produced adventitiously as part of the oil and gas extraction and production process and are not deliberately created.

The NORM deposits in oil and gas production originate from the radioactive decay of the primordial radionuclides U-238 and Th-232 (see Figure 1).

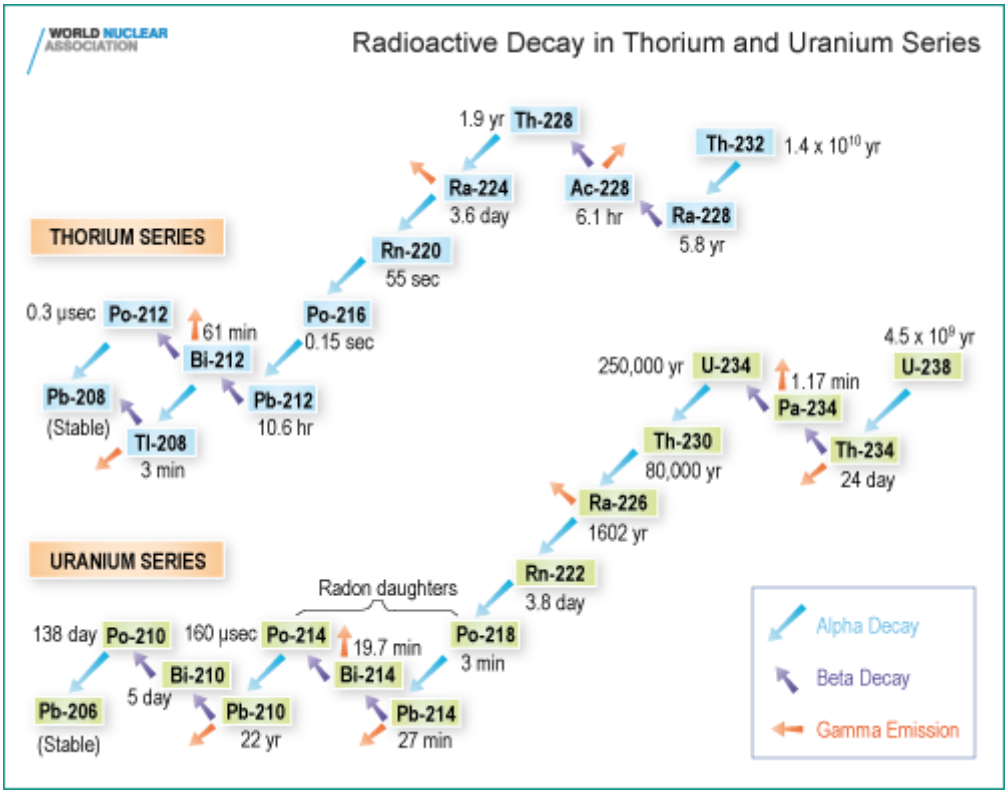

Figure 1: U-238 and Th-232 decay chains

3.2 Produced Waste Products

NORM waste products in oil and gas production can be divided into two main categories: waste from sulphate deposits and waste from carbonate deposits. Sulphate deposits consist mainly of barium sulphate ($BaSO_4$), while carbonate deposits consist of calcium carbonate ($CaSO_4$). The primordial radionuclides uranium and thorium are insoluble in the rock strata in which reside the oil and gas

reservoirs below ground. However, their decayed daughter product radium, is soluble and in geological formations will, under certain circumstances, migrate from the rock strata and be dissolved in the formation water, oil and the gas. The mixing of formation water and fluids create incompatible solutions, causing the precipitation of sulphates of barium and strontium. Like barium and strontium, radium is part of group IIA elements in the periodic table and has similar chemical properties. Consequently, radium is co-precipitated with barium and strontium as a radium sulphate complex.

During oil and gas extraction turbulent flow in the production system can cause the precipitated sulphate salts to attach to the walls and surfaces or to bind to sand and particulates to form deposits including scales with enhanced levels of radioactivity. These NORM contaminated deposits, scale, sand and sludge have the potential to be found inside all types of equipment used in oil production that has been in contact with produced fluids.

As the age of an oilfield increases, there is a requirement to introduce additional fluids into the structure to maintain the hydrostatic pressure and allow continued oil extraction. As the volume of introduced fluids increases there is often a comparable increase in sulphate precipitation and therefore the levels of NORM material increase with age of the site.

4 Waste Management

The IGas waste management policy is to facilitate the sustainable and efficient management of NORM waste in line with the “waste hierarchy” principle (Figure 2). In managing its NORM waste IGas will aim where reasonably practicable to:

- plan for its waste arisings,
- avoid the production of unnecessary NORM waste,
- manage NORM waste arisings in the most environmentally appropriate way.
- Identify with its supply chain a range of management options appropriate to the diversity of wastes produced.

Delivery of its waste management policy is through the IGas Waste Management Procedure (Ref:HSE.PR.007.)

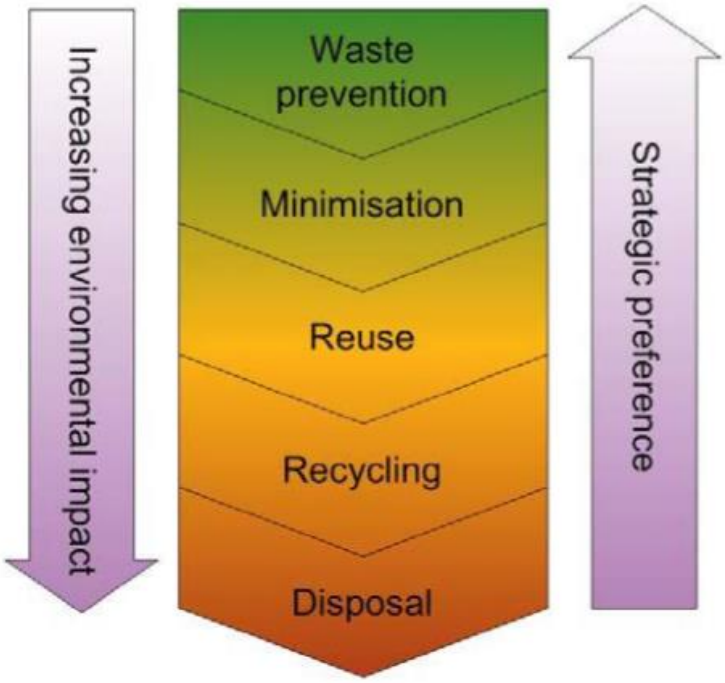

Figure 2: The waste hierarchy

IGas will implement the waste hierarchy and apply the following:

Waste prevention: IGas will separate out NORM as soon as is reasonably practicable before it can become mixed and hence increases waste volumes.

Waste minimisation: IGas will design its processes to minimise the production of NORM waste.

Waste re-use: IGas will endeavour where reasonably practicable to utilise its waste arisings to defer waste production and extend the life of resources.

Waste recycling: IGas will endeavour, where reasonably practicable, to recycle its NORM waste.

Volume reduction: IGas will endeavour, where reasonably practicable, to reduce the volume of NORM waste requiring disposal and will effectively characterise NORM waste such that minimal volumes are sentenced for disposal for each waste category, including identifying NORM waste that is exempt from regulatory control.

Waste disposal: There are several options for the disposal of NORM contaminated wastes in the UK (See also Section 4.1) these are:

- Off-site disposal of solid NORM wastes to a Permitted Landfill Site;
- Offsite disposal of solid wastes for Incineration at a Permitted facility.

- Offsite disposal of aqueous NORM wastes at a Permitted Water Treatment Facility;
- Off-site disposal of aqueous wastes for Incineration at a Permitted facility;

There are other waste disposal options that are in use for the disposal of oil and gas wastes but have been discounted following a government review as not suitable for the UK. (See Section 4.2)

4.1 Waste Disposal Options

4.1.1 Permitted Landfill Site

Solid NORM wastes are well suited for co-disposal with large quantities of non-radioactive trade and household wastes and as such, a Permitted Landfill site can accept large volumes of NORM contaminated solid waste subject to the content conforming to the site conditions for acceptance (CFA). IGas experience has shown that in most of its scale and sludge wastes, the NORM contaminated solid waste cannot comply with the chemical requirements of the CFA due to the hydrocarbon content and levels of heavy metals, in particular mercury. Where the wastes are compliant the use of this disposal route may be considered as applying the principles of BAT.

4.1.2 Permitted Incineration Facility (Solid Waste)

Incineration is suitable for the treatment and disposal of solid NORM wastes and is particularly appropriate for hydrocarbon bearing solid NORM wastes. Certain incineration facilities can recover the energy from the combustion process for additional use.

Where appropriate, the use of this disposal route may be considered as applying the principles of BAT.

4.1.3 Permitted Water Treatment Facility

Consignment of NORM contaminated water to a waste water (effluent) treatment plant is particularly suited to the potentially large volumes of aqueous waste generated during oil and gas production.. Waste water treatment plants already treat several million litres of waste water per day and the addition of NORM bearing water to the feedstock represents a very small proportion of the facilities daily effluent input. The initial NORM activity concentration in the waste water is already relatively low and co-treatment with non-radioactive effluent waters significantly reduces the NORM activity concentrations to negligible levels that are well below the aqueous Out of Scope Levels.

The effluent treatment plant will also separate suspended solid NORM content from the aqueous phase during treatment by filtration. This is part of the normal treatment process of the effluent stream. NORM solids will accumulate in the solid filter cake, but the enormous volumes of effluent being treated results in dilution of the NORM solids which are distributed within a large mass of filter cake. The NORM activity concentration in the solid cake is reduced to negligible levels which are well below the solid Out of Scope Levels. Filter cake has options for re-cycling as a soil improver and fertilizer or as a source of fuel in pressed briquettes.

Where appropriate, the use of this disposal route may be considered as applying the principles of BAT.

4.1.4 Permitted Incinerator Facility (Aqueous Waste)

NORM contaminated water can be sent for incineration, however, the quantities suitable for treatment are relatively small, typically a few hundred litres at a time. The incinerator temperature needs to be significantly increased to accommodate the heat capacity of the water resulting in increased use of fuel (feed gas), discharge of combustion products and environmental impact.

These restrictions tend to make incineration relatively expensive and its use as a disposal route is not considered as applying the principles of BAT where potentially large volumes of NORM contaminated water require disposal.

4.2 Non-Applicable Waste Disposal Options[2]

4.2.1 Disposal in abandoned wells

At this time oil and gas wells in the UK are currently in production or await re-instatement subject to economic operation, and to utilise this option would require long term above ground storage until abandoned wells are available. The geology of the UK landmass would be suitable for the medium-term storage for the longest-lived radioisotope Ra-226 (1600 years). To use this option the scale and sludge would have to be encapsulated, likely in concrete, placed into the well and then plugged. The wells used will require a detailed geological analysis and long-term control to eliminate the risk of blow-out. This option is likely to be costly and given the quantity of NORM at IGas is not a BAT option.

4.2.2 Land Dispersal

This is a long standing waste disposal method that has historically been used by the petroleum industry world wide but not in the UK. It involves the spreading of the wastes with or without dilution over open land relying on natural processes to disperse and bind the waste into the environment. This option is the cheapest option however, given not only the radioactive elements but other potential toxic material this option is not regarded as implementing BAT.

4.2.3 Shallow Land Disposal (Low Level Waste Repository)

The Low Level Waste Repository (LLWR) is the UK's national facility for the disposal of low level radioactive waste. Although there is a requirement that the site should receive all consignments of waste for which no such alternative exists, provided that the waste meets the facility's Waste Acceptance Criteria and radiological capacity constraints, LLWR encourage the use of alternative disposal options. The facility is designated to receive the low-level waste generated by nuclear industry during decommissioning. The limited space in this facility and their stated mission goal means that the operators are reluctant to accept non-nuclear radioactive waste. The historical activity assessments of IGas waste classify them as either exempt and Low Level Waste. The

disposal of the waste at the low level waste repository is expensive per unit item and given the intended purpose of the LLWR this option is not considered as implementing BAT.

4.2.4 Deep Land Disposal

This is a recognised method for the long-term disposal of high and intermediate level waste. At this time, the UK does not have such a facility and any timescale for such a facility becoming available is likely to many years - well into the future. Once in place such a facility is likely to be costly in terms of disposal per unit item and is also likely to be restricted to high/intermediate level wastes due to the capacity of the facility. The likely cost of disposal and the future timescale for its availability mean that this method is not considered an implementation of BAT even if it were to be available.

5 Assessment and Management of Waste Products

5.1 Environmental Management System

IGas have established an environmental management system (EMS) (Ref: QUA.MN.001) to identify, plan and establish the necessary procedures, objectives and targets in association with financial planning and investment to safeguard the environment. This EMS identifies within the company the structure and responsibility for environmental management, the levels of training, awareness and competence of individuals, stakeholder and community engagement, documentation and procedures and the Company's environmental management processes that assure compliance with environmental legislation. As part of the EMS, IGas ensures that its environmental responsibilities and risks are monitored and measured, that records are kept and maintained and actions implemented. In respect of the management of radioactive substances, IGas has appointed an independent Radiation Protection Adviser (RPA) and Radioactive Waste Adviser (RWA) to advise and audit the organisation. Through communication with the RPA/RWA IGas ensures that environmental risks regarding radioactive substances and practices are managed to ensure that environmental risks are reduced to as low as is reasonably practicable.

To ensure that IGas is aware of and able to perform to the highest standards of environmental management, it maintains good working relationships with the environmental regulators (EA/SEPA) and plays an active role as a member of UKOOG (UK Onshore Oil and Gas) the national body representing onshore oil and gas operators. Its EMS is certified to ISO:14001:2004 and externally audited by Lloyds Register QA Ltd.

IGas produce NORM contaminated scales, sludges, sediments and water. The BAT approach to these is similar with specific controls being required dependent on the waste and its stage in the production. For clarity, each waste type has been described along with the controls in separate sub-sections below.

5.2 Extractive Waste (Scales)

5.2.1 Generation

As described in Section 3.2 entrained solids of sulphates are present within the oil and gas flow mixed in with other particulate solids. As oil and gas extraction occurs, these particles are entrained within the fluid flow and taken up towards the surface. Turbulent flow in this extraction system can cause the precipitated salts to attach to the walls or to sand and particulates to form deposits with enhanced levels of radioactivity. As the temperature and pressure decreases on route to the surface the salts can plate out onto pipework, pumps, valves and extraction equipment to form a hard-contaminated scale. Over time the presence of scale can increase to the point that its presence impacts production rates and the scaled equipment is removed from operation and treated. If radium sulphate is amongst the precipitated salts then these scales will be radioactive.

5.2.2 Characterisation/Sorting and Segregation

IGas will use UKAS accredited laboratories to carry out measurements of NORM concentrations in scale samples. Analysis will consist of high resolution gamma spectrometry (HRGS) looking for the presence of NORM radionuclides and chemical analysis for the levels of mercury and hydrocarbons in the wastes.

A sample volume suitable for analysis will be collected by an IGas Radiation Protection Supervisor (RPS) and processed in accordance with the Company's NORM Assessment Procedure. An electronic record of the sample and the subsequent results will be created and retained electronically by IGas. IGas will consult an accredited Radioactive Waste Adviser on the implications of the analysis results in terms of the waste hierarchy and in the event of disposal as waste, the categorisation will be based on activity concentration thresholds in accordance with EPR16.

5.2.3 BAT Considerations

Planning and Design

IGas have identified suitable locations at their sites for the short-term storage of NORM contaminated items and drums of contaminated scale. These locations have been assessed by the RPA/RWA as being suitable and fit for purpose.

IGas have specified a multi stage monitoring process to initially identify the presence of NORM and then to ensure that only material that is contaminated with NORM above exemption and LLW levels is identified for NORM waste disposal.

IGas have identified the need for and implemented NORM specific monitoring and awareness training for all of its well operators. This training has been delivered by the IGas appointed RPA/RWA.

IGas have identified the need for suitable monitoring instrumentation for specifically monitoring for NORM and have procured Tracerco NORM monitors.

Monitoring and reporting

IGas use modern and suitable radiological instrumentation to undertake contamination monitoring. These instruments are tested annually in accordance with requirements of the Ionising Radiations Regulations. IGas have implemented a radiation monitoring training program for their staff which is delivered by their RPA/RWA.

IGas have implemented a monitoring programme for identifying contaminated equipment. Operators have been trained in the use of radioactive monitoring instrumentation to monitor equipment as it is removed from the extraction wells in accordance with a NORM assessment procedure. If NORM contaminated equipment is suspected an RPS is sent to re-monitor and confirm that the measurements are correct and the extent of the contamination. A sample of scale is collected for offsite laboratory analysis to identify the correct categorisation of the waste.

IGas have an integrated electronic database that records all NORM contaminated items or batched wastes material, identifies them with a unique reference number, the sample analysis results, dates of discovery, storage, final disposal dates along with disposal certificates and monitoring information. Where scale is dislodged during activities associated with equipment extraction or breakdown it is collected, placed into a waste drum and a sample collected for analysis.

Minimising Generation of Material

The contaminated scale builds up on plant and equipment which continues to be used until its presence impacts production and it is no longer cost effective to continue operation. At this point the plant/equipment is removed from service. IGas have decided that the equipment and items will be transferred offsite, de-scaled by a contractor so that the equipment may either be re-used or can be transferred for metal recycling. The removed scale is disposed of by the de-scaling contractor on their own premises under the conditions of their own Permit.

IGas are currently investigating ways to reduce the levels of radioactivity transported to the surface in the aqueous phase along with hydrocarbons. It is anticipated that the addition of chemical compounds (chemical treatment) to the well fluids could help prevent or reduce the precipitation of dissolved radionuclides in the aqueous phase. Chemical treatment has the potential benefit of reducing in radionuclide mobility which would potentially leave a larger proportion of NORM in the formation, this could potentially reduce both the volume and radioactivity levels in the generated scale.

Storage of Material

- **Prevention of Loss of Containment**

NORM scale contaminated equipment is stored in a segregated area specifically set aside for storage of this material. This area will either be a bunded location or a lockable iso-container depending on the specific site. Openings to the contaminated equipment (valves pipework etc) will be covered by either a plastic cap or polythene cover. The storage area will be sheeted to protect it

from the elements. The area will be signposted as a Controlled Area and the area will be monitored by an RPS as part of a routine monitoring programme.

In the event of loose scale being generated or found on an IGas site it will be collected and placed into a lined 210 litre metal drum suitable for transport as a Class 7 Industrial Package should the contents fall within the application of the Carriage of Dangerous Goods legislation. This drum will be sealed and placed into the bunded NORM store. The area around the loose scale will be monitored by an RPS and if required, decontaminated to background levels.

- **Prevention from Theft or Loss of Items**

The storage area is on a secure site where access/egress is controlled. Sites maybe be monitored either through CCTV or by the use of passive infra-red detectors (PIR) on site and routine security patrols are carried out.

Each contaminated item or drum of scale is recorded on a spreadsheet to ensure that the site has a continual inventory of contaminated items. This is checked on a weekly basis with a 6 monthly formal audit.

Controlling and minimising the risk of NORM contamination

The storage area for NORM contaminated items and drums of scale is a bunded storage area pre-identified and assessed as being fit for purpose. This area is established as a Controlled Area as defined under Ionising Radiations Regulations and is signed accordingly. The site RPS has responsibility for the area and local rules have been established. Where items are identified as NORM contaminated on operational plant/equipment, then measures are undertaken to remove the contaminated equipment; readily de-contaminable plastic ground sheeting is used to contain and minimise the spread of contamination. Decontamination of the plastic sheet is generally achievable where transitory contact has occurred.

Radiological Impact (if not transferred)

No radiological impact statement is required as the material is transferred to a Permitted Waste Recipient.

5.2.4 Waste Management Option based on BAT

The NORM contaminated items - plant and equipment - can be re-used or they can be recycled. If scale is present on contaminated items these are sent for cleaning and de-scaling. The items are then inspected and either re-used or recycled.

The NORM contaminated scale has no useful purpose and is therefore considered as waste and is transferred to the de-scaling company who dispose of the material under their own environmental Permit.

If IGas have generated quantities of scale from on-site operations the materials will be aggregated into suitable storage units (typically 210 litre metal drums) and transferred to a licensed waste

recipient for disposal. Analysis of the scale samples taken to date have also identified elevated levels of heavy metals including mercury, therefore disposal to landfill is not permissible and scale is transferred directly to the Permitted waste facility for incineration.

5.3 Extractive Waste (Sludge)

5.3.1 Generation

As described in Section 3.2 entrained radioactive solids of sulphates are present within the oil and gas fluids. These are present as particulates in a dense viscous mixture of oil, grease, wax and water. This material is referred to as sludge. If the radioactive sulphates do not precipitate out as scale they may chemically bind to sand and other particulates to form sludge with enhanced levels of NORM. As the oil and gas fluids are processed, the sand and particulates are removed from the refined product ether through gravitational settling or active separation to produce a sludge with enhanced levels of NORM.

5.3.2 Characterisation/Sorting and Segregation

IGas will use UKAS accredited laboratories to carry out measurements of NORM concentration in sludge samples. Analysis will consist of high resolution gamma spectrometry (HRGS) looking for the presence of NORM radionuclides and chemical analysis for the levels of mercury and hydrocarbons.

A sample volume suitable for analysis will be collected by an IGas Radiation Protection Supervisor (RPS) and processed in accordance with the Company's NORM Assessment Procedure. An electronic record of the sample and the subsequent results will be created and retained electronically by IGas. IGas will consult an accredited Radioactive Waste Adviser on the implications of the analysis results in terms of the waste hierarchy and in the event of disposal as waste, the categorisation will be based on activity concentration thresholds in accordance with EPR16.

5.3.3 BAT Considerations

Planning and Design

IGas have identified suitable locations at their site for the short-term storage of NORM contaminated sludge. These locations have been assessed by the RPA/RWA as being suitable and fit for purpose.

IGas have identified a multi stage monitoring process from identifying the presence of NORM to ensure that only sludge that is contaminated with NORM above exemption and LLW levels is identified for NORM waste disposal.

IGas have identified the need and implemented NORM specific monitoring and awareness training for all of its well operators. This training has been delivered by the IGas appointed RPA/RWA. IGas

have identified the need for suitable monitoring instrumentation for specifically monitoring for NORM and have procured Tracerco NORM monitors.

IGas generate relatively small quantities of sludge. This means that the associated volumes of recoverable product are small. IGas has considered product recovery and waste volume reduction using the processes below.

- Sludge pre-treatment (e.g. in a fluidised bed incinerator), the sludges are dewatered and/or de-oiled (by e.g. centrifugal decanters or steam dryers) to reduce their volume and to recover oil from slop equipment
- Reuse of sludge in process units (e.g. coking) as part of the feed due to their oil content

The small volumes of contaminated sludge render recovery impracticable and waste volume reduction by these means is not considered BAT.

Monitoring and reporting

IGas have procured modern and suitable radiological instrumentation to undertake contamination monitoring. These instruments are tested annually in accordance with the requirements of the Ionising Radiations Regulations. IGas have implemented a radiation monitoring training program for their staff which is delivered by their RPA/RWA.

IGas have implemented a monitoring programme for identifying NORM contaminated sludge. Operators have been trained in the use of radioactive monitoring instrumentation to monitor sludge as it is removed from the extraction wells in accordance with a NORM assessment procedure. If any sludge if believed to be NORM contaminated an RPS is sent to re-monitor and confirm that the measurements are correct and the extent of the contamination. A sample of sludge is collected for offsite laboratory analysis to identify the correct categorisation of the material.

The removed sludge is stored within a 210 litre drum certified as suitable for the retention of liquids. IGas have an integrated electronic database that records, all drums of NORM contaminated sludge with a unique reference number, the sample analysis results, dates of discovery, storage, final disposal along with disposal certificates and monitoring information.

Minimising Generation of Material

A well workover, which produces the bulk of the sludge material, is only undertaken when its build up impacts production and it becomes no longer cost effective to continue operation at which point the well is removed temporarily from service and cleaned out to restore fluid flow.

IGas are currently investigating ways to reduce the levels of radioactivity transported to the surface in the aqueous phase along with hydrocarbons. It is anticipated that the addition of chemical compounds (chemical treatment) to the well fluids could help prevent or reduce the precipitation of dissolved radionuclides in the aqueous phase. Chemical treatment has the potential benefit of reducing the radionuclide mobility which would potentially leave a larger proportion of NORM in the

formation, this could potentially reduce both the volume and radioactivity levels in the generated scale.

Storage of Material

- **Prevention of Loss of Containment**

The removed sludge is stored within 210 litre drums suitable for the retention of liquids in accordance with the Carriage of Dangerous Goods legislation. The drums of sludge are stored in a segregated area specifically set aside for storage of NORM. This area will either be a bunded location or a lockable iso-container depending on the site. The area will be sheeted to protect it from the elements. The area will be signposted as a Controlled Area and the area will be monitored by an RPS as part of a routine monitoring programme. IGas have a tested contingency plan as part of their local rules for spillage of sludge from a drum including the catastrophic failure of the drum during movement.

- **Prevention from Theft or Loss of Items**

The storage area is on a secure site where access/egress is controlled. Sites maybe be monitored either through CCTV or by the use of passive infra-red detectors (PIR) on site and routine security patrols are carried out.

Each contaminated drum of sludge is recorded on a spreadsheet to ensure that the site has a continual inventory of contaminated items. This is checked on a weekly basis and a 6 monthly formal audit.

Controlling and minimising the risk of NORM contamination

The storage area for the drums of NORM contaminated sludge is a bunded storage area pre-identified and assessed as being fit for purpose. This area is established as a Controlled Area as defined under the Ionising Radiations Regulations and is signed accordingly. The site RPS has responsibility for the area and local rules have been established for the area.

Where sludge is removed from a well workover the immediate area is covered with readily de-contaminable plastic ground sheeting to minimise the spread of contamination and contain any potential spillage. Decontamination of the equipment and plastic sheet is generally achievable where small drips of sludge have been deposited during operations. The immediate work area around the locations where the loose sludge was deposited will be monitored by an RPS and if required decontaminated to background levels.

Radiological Impact

No radiological impact statement is required as the sludge is transferred to a Permitted Waste Facility.

5.3.4 Waste Management Option based on BAT

The NORM contaminated sludge cannot be reused

The NORM contaminated sludge cannot be recycled.

The NORM contaminated scale has no useful purpose and is therefore considered as waste requiring disposal. The sludge sample by their nature of origin have a high hydrocarbon content and samples taken to date have also identified elevated levels of heavy metals in particular mercury, meaning that transfer to a licensed waste contractor for disposal to landfill is not permissible. NORM contaminated sludge is therefore transferred to a Permitted waste facility for incineration.

5.4 Extractive Wastes (Settled Sediment from Tanks and Vessels)

5.4.1 Generation

Prior to removal from the extraction site or from a field gathering centre the oil and gas undergoes temporary storage before transfer to a refinery. During this storage period additional gravitational settling can occur of fine particulates of a particle size not removed during earlier separation. On occasion these sediments have been found to have elevated levels of NORM.

5.4.2 Characterisation/Sorting and Segregation

IGas will use UKAS accredited laboratories to carry out measurements of NORM concentration in scale samples. Analysis will consist of high resolution gamma spectrometry (HRGS) looking for the presence of NORM radionuclides and chemical analysis for the levels of mercury.

A sample volume suitable for analysis will be collected by an IGas Radiation Protection Supervisor (RPS) and processed in accordance with the Company's NORM Assessment Procedure. An electronic record of the sample and the subsequent results will be created and retained electronically by IGas. IGas will consult an accredited Radioactive Waste Adviser on the implications of the analysis results in terms of the waste hierarchy and in the event of disposal as waste, the categorisation will be based on activity concentration thresholds in accordance with EPR16.

5.4.3 BAT Considerations

Planning and Design

IGas have identified suitable locations at their site for the short-term storage of NORM contaminated sediments. These locations have been assessed by the RPA/RWA as being suitable and fit for purpose.

IGas have specified a multi stage monitoring process to initially identify the presence of NORM and then to ensure that only material that is contaminated with NORM above exemption and LLW levels is identified for NORM waste disposal.

IGas have identified the need for and implemented NORM specific monitoring and awareness training for all of its well operators. This training has been delivered by the IGas appointed RPA/RWA.

IGas have identified the need for suitable monitoring instrumentation for specifically monitoring for NORM and have procured Tracerco NORM monitors.

IGas generate relatively small quantities of settled sediment. This means that the associated volumes of recoverable product are small. IGas has considered product using the processes below.

- Sediment pre-treatment (e.g. in a fluidised bed incinerator), the sediments are dewatered and/or de-oiled (by e.g. centrifugal decanters or steam dryers) to reduce their volume and to recover oil from slop equipment.
- Reuse of sediment in process units (e.g. coking) as part of the feed due to their oil content

The small volumes of contaminated sediment render recovery impracticable and waste volume reduction by these means is not considered BAT.

Monitoring and reporting

IGas have procured modern and suitable radiological instrumentation to undertake contamination monitoring. These instruments are tested annually in accordance with the requirements of the Ionising Radiations Regulations. IGas have implemented a radiation monitoring training program for their staff which is delivered by their RPA/RWA.

The base of settling vessels and tanks are monitored in accordance with a site based monitoring programme. If elevated radiation readings are established then the settled sediment is collected and sent for offsite laboratory analysis to identify the correct categorisation of the material.

The removed sediment is stored within a 210 litre drums suitable for the retention of liquids. IGas have an integrated electronic database that records, all drums of NORM contaminated sediment with a unique reference number, the sample analysis results, dates of discovery, storage, final disposal along with disposal certificates and monitoring information (Note: to minimise the volume of waste in the majority of cases the NORM contaminated sediment is placed into drums containing NORM sludge. The specific bag of sediment retains its unique reference number but its storage location may be referenced with other material (sludge).

Storage of Material

- **Prevention of Loss of Containment**

The removed sediment is stored within a 210 litre drums suitable for the retention of liquids in accordance with the Carriage of Dangerous Goods legislation. These drums are stored in a segregated area specifically set aside for storage of NORM. This area will either be a bunded location or a lockable iso-container. The area will be sheeted to protect it from the elements. The

area will be signposted as a Controlled Area and the area will be monitored by an RPS as part of a routine monitoring programme. IGas have a tested contingency plan as part of their local rules for spillage of sludge from a drum including its catastrophic failure during movement.

- **Prevention from Theft or Loss of Items**

The storage area is on a secure site where access/egress is controlled. Sites maybe be monitored either through CCTV or by the use of passive infra-red detectors (PIR) on site and routine security patrols are carried out.

Each contaminated drum of sediment is recorded on a spreadsheet to ensure that the site has a continual inventory of contaminated items. This is checked on a weekly basis and a 6 monthly formal audit.

Controlling and minimising the risk of NORM contamination

The storage area for the drums of NORM contaminated sludge/sediment is a bunded storage area pre-identified and assessed as being fit for purpose. This area is established as a Controlled Area as defined under the Ionising Radiations Regulations and is signed accordingly. The site RPS has responsibility for the area and local rules have been established for the area. Where sediment is removed from the base of a tank or vessel following its emptying the immediate area is covered with impermeable ground sheeting to minimise the spread of contamination and contain any potential spillage. Decontamination of the equipment and sheet is generally achievable where small drips of sediments have been deposited during these operations.

5.4.4 Waste Management Option based on BAT

The NORM contaminated sediment cannot be reused

The NORM contaminated sediment cannot be recycled.

The NORM contaminated sediment has no useful purpose and is therefore considered as waste requiring disposal. The samples by their nature of origin have a high hydrocarbon content and samples taken to date have also identified elevated levels of heavy metals in particular mercury, meaning that transfer to a licensed waste contractor for disposal to landfill is not permissible. NORM contaminated sediment is therefore transferred with contaminated sludge to a Permitted waste facility for incineration.

5.5 Contaminated Soft Waste

5.5.1 Generation

During the handling and maintenance of NORM contaminated items and waste materials IGas employ the use of personal protective equipment (PPE) where other control measures cannot adequately control the risk of contact with oil and NORM contamination. Such PPE could include disposable wipes, coveralls, gloves and face masks.

5.5.2 Characterisation/Sorting and Segregation

Where a particular well is known to produce NORM contaminated material, the PPE and soft waste are monitored at the site by a trained Radiation Protection Supervisor. If elevated levels of contamination above background are identified the contaminated item is separated from other waste and placed into a separate disposal vessel. Prior to decontamination a decision is made by the RPS on whether decontamination of soft waste will generate additional soft waste outweighing the benefit of the decontamination process.

Any soft waste contaminated with oil is separated from non-contaminated soft waste. The non-contaminated soft waste is sorted for re-cycling either on the site or is sent for sorting with an offsite contractor to minimise the waste sent to landfill and to maximise recycling. Contaminated coveralls are washed and re-used.

5.5.3 BAT Considerations

Planning and Design

In accordance with the principles for the mitigation of risk, IGas only utilise PPE where it is not reasonably practicable for other controls measure to be implemented for the purposes of controlling risk.

Minimising Generation of Material

Staff are aware that NORM contaminated PPE should be kept to a minimum and whenever possible monitoring should be carried out to confirm if the material comes within the scope of EPR16. In the majority of cases due to the presence of oil on the PPE the material is not suitable for the disposal with general waste and requires specialist disposal.

IGas will use protective sheeting to form temporary bunds and sheeting to minimise the radiological impact from any spillage or loss of material during work where a method statement identifies a potential loss of containment of NORM contaminated material. Where practicable any spillage is wiped up and the area monitored, further decontamination may occur until the material can be categorised as free from NORM contamination subject to a decision being made on the benefit versus the additional soft waste generated during the decontamination process.

Radiological Impact (if not transferred)

No radiological impact statement is required as the PPE and soft waste is transferred to a Permitted Waste Facility.

5.5.4 Waste Management Option based on BAT

The NORM contaminated soft waste cannot be reused

The NORM contaminated soft waste cannot be recycled.

The NORM contaminated soft waste has no useful purpose and is therefore considered as waste requiring disposal. Where reasonably practicable soft waste maybe decontaminated at source to ensure that as much material as possible is out of scope of regulatory control. This material is therefore, disposed via other waste routes available to IGas.

5.6 Fluid (Surface Water Run Off/Rainwater)

5.6.1 Generation

IGas sites, due to the nature of the work, have a significant footprint that is open to the elements. As part of the storage arrangements and for protection of the environment many of the tanks and process vessel are bunded as a contingency against the failure of vessel containment and potential spill of oil. These bunded areas will collect rainwater which IGas treat as potentially contaminated with hydrocarbon residue and in the case of sites where NORM has been identified this water is considered as potentially NORM contaminated.

5.6.2 Characterisation/Sorting and Segregation

Meteoric rainfall collected in bunds where NORM contaminated material is stored will be collected and re-injected into hydrocarbon bearing reservoirs for pressure support.

Should it be necessary to transport the fluid offsite to a third party IGas will use UKAS accredited laboratories to carry out measurements of NORM concentration in surface water runoff where it is known that it has originated in a bunded area containing NORM contaminated material. Analysis will consist of high resolution gamma spectrometry (HRGS) looking for the presence of NORM radionuclides and chemical analysis for the levels of mercury and hydrocarbons.

A sample volume suitable for analysis will be collected by an IGas Radiation Protection Supervisor (RPS) and processed in accordance with the Company's NORM Assessment Procedure. An electronic record of the sample and the subsequent results will be created and retained electronically by IGas. IGas will consult an accredited Radioactive Waste Adviser on the implications of the analysis results in terms of the waste hierarchy and in the event of disposal as waste, the categorisation will be based on activity concentration thresholds in accordance with EPR16.

5.6.3 BAT Considerations

Planning and Design

The IGas sites have been designed to provide containment in the event of spillages or loss of containment from their vessels and tanks. IGas have designed these units on the assumption that they will in addition collect and contain surface water runoff/rainwater and have been designed that this material can be collected and removed.

Minimising Generation of Material

Surface water runoff is collected separately from those parts of IGas sites where NORM contamination could potentially occur. This reduces the volume of potentially affected water and reduces the potential for cross contamination of NORM waters with general surface runoff/rainwater.

Storage of Material

Surface water will remain in place if it is to be transported offsite to a third party until the laboratory analysis results are returned from the laboratory. This area will be a bunded location of a suitable size to adequately contain all of the liquid volume stored in the area. The area will be sheeted to protect it from the elements. The area will be signposted as a Controlled Area and the area will be monitored by an RPS as part of a routine monitoring programme. IGas have a contingency plan as part of their local rules. Waste Management Option based on BAT

Surface water run-off/rainwater will be re-used on the site where IGas can demonstrate that the water is used to support the production of further hydrocarbons. This water will be mixed with produced water and re-injected either at the same site or at a different IGas site provided that the laboratory analysis results show that the material is uncontaminated by site activities.

If water is not being re-injected to support the production of further hydrocarbons the water will be either sent for treatment to a water treatment plant subject to the results of chemical analysis. If the NORM contamination levels are above the exemption limits identified in EPR16 the water will be sent to a Permitted water treatment facility able to accept radioactively contaminated water.

5.7 Produced Water

5.7.1 Generation

Produced water can contain enhanced levels of dissolved NORM and particulate NORM in suspension. NORM in Produced water can plate out on equipment and depending on the suspended solids/particulates may result in the water itself being classed as NORM radioactive material.

5.7.2 Waste Management Option based on BAT

A number of studies have shown that the best environmental option for the disposal of Produced Water is re-injection for disposal at the original site or at a different site into geological formations from which hydrocarbons have been extracted, or which for natural reasons have been designated by the Environment Agency as permanently unsuitable. This option for disposal is identified in the Onshore Oil and Gas Sector Guidance Document version 1 August 2016 as being the best environmental option to minimise the exposure to the public to ionising radiation from the disposal of radioactive waste and is in accordance with the UK NORM strategy.

5.7.3 BAT Considerations for Off Site Disposal

Where water re-injection for disposal at the original site or at a different site into geological formations from which hydrocarbons have been extracted is not the BAT option for logistical or technological reasons; IGas will aim to remove insoluble particulates by allowing particulates to settle and the

liquor to be removed, this has the potential to reduce the volumes and types of waste disposed of to respective waste streams. The waste water will be transferred to a Permitted waste water treatment facility and the solids disposed of to a suitable permitted waste facility.

6 References

1. Environmental Permitting (England and Wales) Regulations 2016

2. IAEA Safety Report No. 34 Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry

3. Environment Agency - Onshore Oil and Gas Sector Guidance Document version 1 August 2016