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Decommissioning Framework for Offshore and Oil and Gas Installations.

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Decommissioning an offshore oil and gas installation generates large volumes of waste materials, some of which can be classified as hazardous. This, coupled with the changes in operators, workforce and numerous legislations and regulations, means that decommissioning process is complex and subject to confusion. This paper outlines a decommissioning framework for offshore oil and gas installations, which aims to provide guidance throughout the decommissioning process as well as bringing clarity, consistency and sustainability to the process. The framework is informed by previous research findings, including the analytical hierarchy process findings, the Bayesian network and discussions with industry experts, which highlighted key factors in handling hazardous waste. The key factors included understanding the legislation, sharing effective knowledge, and identifying waste materials. The framework has been applied to a historical case study to demonstrate its relevance and effectiveness.

Keywords: Decommissioning, framework, waste.

1. Introduction

Since the discovery of oil and gas within the United Kingdom Continental Shelf (UKCS), legislation and regulations governing the industry have been ever-changing (Kemp 2011). Post Piper Alpha, a fundamental shakeup of offshore health and safety management occurred. Following the publication of the Cullen Report in 1990, all 106 of the recommendations (Cullen 1990) were put into place including new goal setting safety regulations. The regulations that have since been developed, have been integral to the oil and gas industry, and the recent Deepwater Horizon accident has highlighted their importance (Tikka et al 2024). Within the UK, a legislative framework applies to offshore oil and gas from exploration to production to decommissioning and end of life. Formal regulatory frameworks began to be developed in the early 1900s (Martin 2024). Environmental management systems moved to become focused on risk management and legal compliance. A framework can be used as a guidance document based on regulation, legislation, and best practices.

Frameworks have been successfully used in the nuclear industry, focusing on safe handling and the use of materials since the Manhattan Project in the 1940s (Chater 2005). With the development of nuclear power in the commercial sector during the 1950s, these frameworks were developed further with an emphasis on safety and security (Gu 2018). Current nuclear frameworks are comprehensive, covering radiation protection and waste management to emergency preparations (Krahn & Sowder 2024). Within the UK, general advisory bodies and government departments are stakeholders in the nuclear decommissioning process. There are several similarities between nuclear decommissioning and oil and gas decommissioning projects, as well as several differences. Due to the scale and maturity of nuclear decommissioning and the amount of research that has been conducted, there is a vast amount of information available concerning decommissioning projects.

2. Aims & Objectives

This conference paper aims to provide guidance and bring clarity, consistency, and sustainability to the decommissioning process for offshore oil and gas installations by presenting a framework informed by research and expert input, focused on effectively handling hazardous waste.

The aim will be met through the following objectives:

i. The development of a decommissioning framework using the findings of previous research.
ii. The demonstration the framework's relevance and effectiveness through the application to a historical case study.

3. Methodology

The framework presented in this conference paper forms part of a more extensive research study currently being undertaken at Liverpool John Moores University. The initial stage of the research study included a comprehensive literature review, a pairwise comparison questionnaire formulated using expert opinion obtained during initial discussions, the application of an analytical hierarchy process and the development of a series of Bayesian networks in order to determine the interaction by the identified key factors. Existing nuclear frameworks were analysed and used to develop the proposed decommissioning framework.

The proposed decommissioning framework is designed to enhance the handling hazardous waste materials and improve sustainability outcomes in offshore oil and gas decommissioning. However, several assumptions and limitations must be acknowledged to clarify the framework's scope, applicability, and constraints.

Scope of Application – The framework has been developed for offshore oil and gas decommissioning within the UKCS. While some principles may be applicable to other regions, variations in regulatory frameworks, environmental policies, and industry best practices could influence the effectiveness of the proposed approach outside the UK.

Comparison with Nuclear Decommissioning – The comparison between nuclear decommissioning and oil and gas decommissioning provides valuable insights into best practices. However, fundamental differences in waste classification, radiological hazards, and risk management requirements limit the extent to which nuclear decommissioning methodologies can be directly applied to oil and gas decommissioning projects.

Regulatory Compliance Assumptions – The framework assumes that all operators and contractors fully comply with UK regulations and industry guidelines. However, variability in regulatory interpretations and enforcement could affect real-world implementation.

Data Availability and Transparency – The framework relies on data from publicly available decommissioning reports, expert insights, and case studies. While these provide useful guidance, incomplete or inconsistent reporting of hazardous waste management practices may introduce gaps or uncertainties in the framework's recommendations.

Generalisation of Waste Handling Practices – The framework categorises hazardous waste management strategies based on general industry practices. However, specific waste streams (e.g., radioactive waste, contaminated drill cuttings, or chemical residues) may require customised handling procedures beyond the framework's scope.

Assumption of Stakeholder Collaboration – The framework emphasises knowledge sharing and stakeholder engagement as key components of successful decommissioning. However, variations in industry practices, confidentiality agreements, and competitive interests may limit the extent to which operators and contractors share best practices and lessons learned.

Despite these limitations, the framework provides a structured methodology for improving hazardous waste management and regulatory compliance in offshore decommissioning. Future refinements could incorporate real-time data collection, adaptive regulatory updates, and expanded case study analyses to enhance its applicability across different decommissioning projects.

4. Proposed Decommissioning Framework

4.1 *Scope & Application*

This framework is designed to be flexible enough to be used for different types of installation and by different stakeholders. It is not designed to be used in place of any legislation or regulatory requirements but to be used alongside as guidance.

4.2 *Framework Structure*

This framework focuses on the key principles identified as most important to the sustainable handling of hazardous waste materials during decommissioning. Each component contains an overview, purpose statement, and expectations that define the intended outcome. The proposed structure and the interaction of each element is shown in Fig. 1.

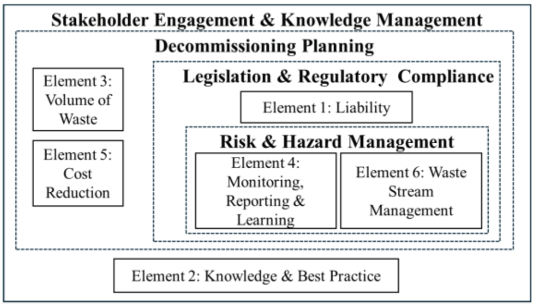

Fig. 1. Proposed framework structure.

4.3 *Fundamental Considerations*

Successful decommissioning requires a strong understanding of legislation, liabilities, and stakeholder responsibilities to minimize compliance risks. Clear communication of obligations across all parties, including waste handlers and transporters, is essential. Knowledge-sharing platforms and decommissioning close-out reports play a key role in improving efficiency and safety. Establishing a central knowledge-sharing database allows best practices to be shared across projects, ensuring continuous improvement. Identifying hazardous waste early is critical. Installations should maintain an up-to-date waste inventory, tracking materials from offshore to onshore disposal. A comprehensive survey at the early decommissioning stages ensures proper classification and handling, reducing the risk of mismanagement. Waste transport, treatment, and disposal must align with current regulations, with clear documentation to ensure transparency and compliance.

Following well isolation and closure, equipment must be decontaminated or sealed for transport to shore. The decontamination technique relies on the identification of materials present during the survey and inventory generation.

In order to maximise sustainability, ultimately, materials and equipment should be recycled or reused. This may not always be possible, depending on the nature of the materials and equipment. Information about the nature of the materials and equipment must be passed on from offshore to onshore stakeholders. This is important to prevent accidents from occurring, resulting in environmental events, injury or death.

4.4 Elements

Element 1 – Liability.

The understanding of liability during the decommissioning process is essential to its success. In order to understand liabilities, there must be an understanding of legislation and regulations.

Purpose Statement: To ensure all parties are aware of their obligations and liabilities, thereby safeguarding the company and stakeholders throughout the decommissioning process.

Expectations:

i. Initial liabilities across the waste stream from offshore to onshore are identified.
ii. Management updates this to include any waste handlers and transporters.
iii. Individual requirements and commitments are identified through the identification of liability.
iv. Effective communication is maintained.
v. Liability and obligations are communicated across all levels.
vi. Policies, standards, and procedures are kept up to date with legislation and regulations and are achievable.

Element 2- Knowledge & Best Practice. Knowledge and best practice sharing, as well as lessons learnt, enable the improvement, efficiency and safety of decommissioning projects. It also assists with the identification, handling and treatment of waste materials.

Purpose Statement: To improve decommissioning processes by preventing accidents and ensuring proper handling and treatment of waste materials through shared knowledge and best practices.

Expectations

i. Lessons learned are published in decommissioning close-out reports.
ii. Dialogue and forums are established between stakeholders.
iii. A central knowledge-sharing database/forum is established for information sharing between projects.
iv. Commitment to learning from internal and external sources.
v. Effective communication mechanisms are established.
vi. Good relationships and an environment where feedback is encouraged and welcomed are established.
vii. Continuous improvement is supported.
viii. Performances are evaluated, and feedback is provided at each stage of decommissioning.
ix. Positive relationships are established to enable thorough communication.

Element 3 – Volume of Waste

Reducing the volume of waste produced is critical to improving the sustainability of a project. By reducing waste, reuse and recycling will be increased. This helps to meet UN sustainability goals and government guidelines as well as improve public image and opinion.

Purpose Statement: To enhance sustainability by minimising waste, promoting reuse and recycling, and aligning with government guidelines and public expectations.

Expectations:

i. Waste materials are correctly identified, and volumes are estimated.
ii. Possible reuse of equipment is explored, and industry experts are consulted.
iii. Waste materials are contained and transported to avoid contamination and accidents.
iv. Equipment is rigorously decontaminated.
v. Waste recyclers are consulted.
vi. Best practices are shared.
vii. Knowledge of up-to-date legislation is maintained.

Element 4: Monitoring of Materials, Reporting & Learning.

Close monitoring of materials during the decommissioning process is essential. This includes volumes, permits, destinations, and types of material.

Purpose Statement: To maintain accurate records and ensure compliance with regulations through diligent monitoring and reporting of materials.

i. Waste material and equipment inventories/registers are kept up-to-date, including volumes, location, and transport mode.
ii. Knowledge and best practice sharing across projects.
iii. Communication between stakeholders and personnel onshore and offshore.
iv. Plans and procedures are maintained in accordance with legislation/regulations/guidance.
v. Monitoring requirements and links to liability are communicated across all levels.
vi. Regular testing, inspections, and surveys are conducted to monitor volumes and locations of waste.
vii. A culture of responsibility is established among the workforce.

Element 5 - Cost reduction.

Cost reduction helps to meet government requirements. Through the reduction of costs, the volumes of waste produced will be addressed.

Purpose Statement: To achieve cost savings while ensuring waste handling processes favour recycling and reuse over disposal.

Expectations:

i. All costs are assessed, and competitive quotes are obtained.
ii. Options to reduce the cost of waste handling are explored without favouring disposal over recycling or reuse.
iii. Recycling or reuse of materials is prioritised wherever possible.
iv. Processes are in place to continually monitor costs throughout the project.
v. Key performance indicators are clearly defined and communicated.
vi. A culture of reuse/recycling alongside cost reduction is established.

Element 6 -Waste Stream.

Minimising the length of the waste stream is crucial for efficient waste management.

Purpose Statement: To streamline the waste stream, reducing handovers and ensuring accountability at all stages.

Expectations:

i. The waste stream is reduced in length to minimise changes/handover of materials.
ii. Liability across waste streams is identified.

iii. Waste definition across boundaries is updated and understood.
iv. Reputable parties are used.
v. Adequate supervision and accountability are maintained across all stages of the waste stream.

4.5 *Discussion*

Frameworks serve to provide a common understanding, guide actions, and facilitate collaboration among stakeholders involved in addressing a complex challenge. In the context of decommissioning projects, a framework aims to enhance consistency and clarity by providing a shared understanding of key factors, processes, and responsibilities. It would promote consistency in approach and reduce ambiguity in decision-making. Frameworks incorporate best practices and lessons learned from previous experiences, helping stakeholders to avoid common pitfalls and implement effective solutions. It would also provide a platform or mechanism for sharing knowledge, expertise, and best practices among stakeholders, fostering a collaborative and learning-oriented environment in the future.

The results of the previous chapters have indicated that the key factors affecting the sustainability of the handling of hazardous waste materials during the decommissioning process are:

i. Understanding of legislation and regulations
ii. Knowledge and best practice sharing
iii. Identification of waste materials

A recurring theme is the critical need for a comprehensive and shared understanding of the complex web of legislation and regulations governing hazardous waste management in the decommissioning process. This complexity is compounded by the involvement of multiple stakeholders with potentially differing interpretations of legal requirements and their respective responsibilities.

Inadequate knowledge sharing among stakeholders has a detrimental effect on the decommissioning process and hinders the effective management of hazardous waste, potentially leading to poor decisions and increased risks. A collaborative approach, where knowledge and best practices are openly shared and disseminated, fostering a culture of collective responsibility and continuous improvement, would aid in the sustainability of the decommissioning process.

Accurate identification and characterisation of hazardous waste have also been identified as a crucial factor in ensuring its proper handling, treatment, and disposal. Incomplete inventories, inadequate surveys, and insufficient testing increase the likelihood of misclassification, potentially resulting in hazardous materials being inappropriately managed, leading to environmental contamination and safety hazards. This emphasises the need for robust procedures and comprehensive data collection to ensure the reliable identification of hazardous waste throughout the decommissioning process.

The proposed framework should aim to enhance regulatory clarity through the promotion of a clear and consistent understanding of applicable legislation and regulations among all stakeholders. This could involve developing guidance documents, training programs, and collaborative platforms for sharing interpretations and best practices. It should facilitate open communication and knowledge exchange among stakeholders. This could include establishing industry forums, knowledge repositories, and mentoring programs to capture and disseminate valuable experience and expertise.

The framework should develop and implement standardised procedures for identifying, characterising, and documenting hazardous waste. This would ensure consistency and accuracy, reducing the risk of misclassification and inappropriate handling.

The framework should encourage the adoption of best practices for minimising waste volume, reducing waste stream length, and prioritising reuse and recycling over disposal. This could involve incentivising sustainable approaches and providing guidance on implementing such practices.

5. Application of Proposed Framework to a Decommissioned Installation

5.1 *Introduction – Goldeneye*

Within the Moray Firth Basin, approximately 100 km off the Northeast coast of Scotland, lies the Goldeneye gas-producing field 14/29, 14/28b, 20/30b and 20/40b. The field was discovered in 1996 (Stewart & Marshall 2020). Gas production started in 2004, cessation of production was granted in 2011(Shell, 2024), and well abandonment was completed in 2018.

The Goldeneye platform was operated by Shell (52.5%) on behalf of Esso (39%), Lasmo (4.5%), Paladin (3%) and Veba (1%) (Offshore Technology 2002). The platform was a normally unattended (NUI) wellhead platform, with 1,400 tonnes topside, five platform wells in 120 m water, and a direct tie-back to the St. Fergus onshore facility (Shell 2024).

The platform consisted of a four-leg piled steel jacket anchored by eight piles. The platform included wellhead equipment, detection, measurement and control facilities, 12-man overnight accommodation, a crane and a helideck (Offshore Technology 2002).

The draft decommissioning programme was submitted to BEIS in 2018 and approved in 2019. The removal and dismantlement of the topside were carried out by Heerema Marine Contractors, the onshore dismantlement was conducted by AF Offshore Decom (Norway) and the subsea removals were completed by DeepOcean (Shell 2024). The initial decommissioning programme encompassed the proposed decommissioning activities for the topsides, jacket, wells and subsea infrastructure up to but excluding the main pipeline tie-in flanges.

5.2 *Summary of Decommissioning Programme*

The Goldeneye decommissioning programme followed four phases: (1) bulk hydrocarbon removal, (2) well plug & abandonment, (3) platform disconnection and removal, and (4) subsea remediation. The 1280-tonne topside and 3019-tonne jacket were dismantled and sent to AF Environmental Base, Norway (Kilow 2021). Offshore process equipment was flushed, purged, and decontaminated before onshore disposal (Shell 2024). Further cleaning and decontamination took place onshore. The close-out report submitted to BEIS, detailed the materials removed, permits for waste transfer applied for, environmental monitoring and lessons learned.

5.3 *Waste Materials*

The initial volumes of waste and the actual volumes of waste generated are shown in Table 1. It can be seen that there were discrepancies between the values. The volume of hazardous water and materials increased from the original estimate as it was found that approximately 250 tonnes of carbon steel was contaminated with heavy metals from paints and coatings (Shell 2024). For the installation, 94.9% of the waste materials were reused, recycled or used for energy recovery. The remaining 5.1% was sent to landfill. The as-weighed values from the heavy lift vessel and the yard showed a 0.16% difference in values.

Table 1. Materials and waste returned to shore (Shell 2024).

Material/ Waste	Original Estimate (Te)	Tonnage to Shore (Te)	Disposal Method
Carbon Steel	8745	3980	3269Te reused 3304Te recycled 407Te recycled following PUI campaign
Stainless Steel	141	120	Recycled
Non-Ferrous Metals	113	64	Recycled
Concrete	123	134	Reuse
Plastics	30	0	The plastics were included within the non-hazardous material for energy recovery.
Haz Mat/Norm	2	267	3.3Te recycled 1.6Te Energy recovery 262Te landfill
Other Non-Hazardous	608	148	5.4Te Reuse 133.6Te Recycling 9.1Te Energy Recovery

5.4 *Lessons Learned*

The close-out report submitted to BEIS by Shell outlined the lessons learned from the decommissioning project. The areas identified for improvement were:

i. Identification of hazards for mobilisation and demobilisation.
ii. Applications for transfrontier shipment of waste.

iii. Identification of hazardous waste – particularly in the fire protection materials.
iv. Handling of radioactive sources in ionising smoke detectors.
v. Awareness of the roles and responsibilities of the Duty Holder, contractors, and sub-contractors.

5.5 Application of Framework

The framework proposed was applied to the Goldeneye installation decommissioning project.

Element 1 – Liability

Purpose Statement: To ensure all parties are aware of their obligations and liabilities, thereby safeguarding the company and stakeholders throughout the decommissioning process.

Application to Goldeneye:

Initial liabilities: Identified across the waste stream from offshore to onshore, including the repatriation of ionising smoke detectors.

Management updates: Included waste handlers and transporters, ensuring compliance with transfrontier shipment regulations.

Individual requirements: Identified through the Permits and Consents Familiarisation session.

Effective communication: Maintained through sessions with contractors and subcontractors.

Policies and procedures: Updated to reflect the latest regulations, such as the Transfrontier Shipment of Radioactive Waste and Spent Fuel (EU Exit) Regulations 2019.

Element 2 – Knowledge & Best Practice

Purpose Statement: To improve decommissioning processes by preventing accidents and ensuring proper handling and treatment of waste materials through shared knowledge and best practices.

Application to Goldeneye:

Lessons learned: Captured in close-out reports and shared during Lessons Learned sessions.

Dialogue and forums: Established between Shell, Heerema Marine Contractors, and AF Decommissioning.

Knowledge-sharing database: This could be implemented to store and share information from the Permits and Consents Familiarisation session and HIRA exercises.

Commitment to learning: Demonstrated through continuous improvement and feedback mechanisms.

Element 3 – Volume of Waste

Purpose Statement: To enhance sustainability by minimising waste, promoting reuse and recycling, and aligning with government guidelines and public expectations.

Application to Goldeneye:

Waste identification: Included ceramic fibres and ionising smoke detectors.

Reuse of equipment: Explored during the dismantling process.

Containment and transport: Ensured to avoid contamination, particularly for hazardous materials like ceramic fibres.

Decontamination: Rigorous decontamination of equipment before disposal or recycling.

Element 4 – Monitoring of Materials, Reporting & Learning

Purpose Statement: To maintain accurate records and ensure compliance with regulations through diligent monitoring and reporting of materials.

Application to Goldeneye:

Waste inventories: Kept up to date, including volumes and locations of waste, like ionising smoke detectors.

Communication: Maintained between stakeholders onshore and offshore.

Plans and procedures: Aligned with regulations, such as those for the transfrontier shipment of waste.

Regular inspections: Conducted to monitor waste volumes and locations.

Element 5 – Cost Reduction

Purpose Statement: To achieve cost savings while ensuring waste handling processes favour recycling and reuse over disposal.

Application to Goldeneye:

Cost assessment: Competitive quotes obtained for waste handling.

Cost reduction options: Explored without compromising on recycling or reuse.

Recycling prioritisation: Ensured for materials like ionising smoke detectors.

Monitoring costs: Throughout the project to identify savings opportunities.

Element 6 – Waste Stream

Purpose Statement: To streamline the waste stream, reducing handovers and ensuring accountability at all stages.

Application to Goldeneye:

Waste stream reduction: Minimised changes and handovers of materials.

Liability identification: Across the waste stream, particularly for hazardous materials.

Waste definition: Updated and understood across boundaries.
Reputable parties: Used for waste handling and disposal.
Supervision and accountability: Maintained throughout the waste stream.

6. Conclusion

A framework was proposed to be used during the decommissioning process, based on the identified key principles for sustainable handling of hazardous waste materials. This framework was structured around liability, knowledge sharing, waste volume reduction, materials monitoring, cost reduction, and waste stream management. The framework is intended to be used as guidance and not replace any legislation
The proposed framework was applied to a historical case study for a decommissioned installation. The decommissioning of the Goldeneye installation illustrates how a decommissioning project within the UK can be conducted. The project involved several different stakeholders and transfrontier shipments. These involved hazardous waste not being identified and the understanding of roles and responsibilities. Despite the project being conducted by an experienced operator, issues still arose. Through the application of the framework proposed, it can be seen that these factors affected the volume of hazardous waste produced and the amount of recycling and reuse of materials, by addressing these issues and improving the quality of surveys and inspections prior to the commencement of dismantling and ensuring that all stakeholders understand their own and each other's roles and responsibilities, the handling of the hazardous waste materials can be improved.

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