[UNCLASSIFIED]

Assessing uptake and impacts of mercury and other contaminants associated with offshore petroleum structures

Proposal for a PhD project supported by industry

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This document summarises a proposal for a PhD project hosted at ANSTO. Objectives, methodology, proposed outcomes, milestones and timings and a profile of the research team are included.

Summary

There has been little work in defining the specific chemical and radiological effects to marine organisms from contaminant scales or residues associated with offshore infrastructure that include metals and naturally occurring radioactive materials (NORM) from the uranium and thorium decay chains. Subsea contaminants include pipeline metals and scales, as well as metals associated with cuttings. This research, which will form a three year PhD project, aims to conduct a series of laboratory tests with material from the industry partner to understand the bioavailability, uptake and assimilation into organisms of associated Contaminants of Primary Concern (COPC).

Assessment of the contaminant's solubility in seawater and acidic solutions (i.e. to mimic the solubility in an organisms' gut) and comparison of the results against environmental guidelines as well as conducting desktop biota dose modelling for comparison against international benchmarks will be conducted where relevant. While there are national water and sediment quality guidelines in place in Australia to provide protection levels for Australian marine biota (i.e. ANZG 2018), these guidelines do not cover NORMs. Furthermore, the toxicological effects from NORMs on marine ecosystems, specifically Australian faunal species, have not been adequately investigated (ARPANSA, 2004).

The project will seek to conduct controlled laboratory bioaccumulation exposures to a range of marine fauna, under a range of environmental conditions. It is crucial to understand the specific bioaccumulation potential of scale-associated contaminants to marine biota in order to more accurately characterise the risk associated with potential exposure to these contaminants, especially for decommissioning planning.

Radioisotope tracers of inorganic mercury (i.e. Hg^{2+}) and organic (i.e. methylmercury) will be used in controlled laboratory studies to increase our understanding of mercury bioavailability, bioaccumulation and biodistribution (i.e. organ translocation) within biota associated with mercury-impacted scale. ANSTO is currently developing inorganic and organic radiotracers of mercury that can be used for this purpose. If significant bioaccumulation of contaminants is determined, assays will be conducted on individuals using molecular assays to understand if fitness can be affected on a molecular level.

Aims and Objectives

This project will comprise of two major aims through the application of ecotoxicological principles and organism-contaminant exposure modelling to:

(1) Determine primary exposure pathways and organ distribution parameters of infrastructure-associated contaminants (predominantly mercury) to bottom-dwelling (benthic) marine organisms and,

(2) Assess the potential individual and population-level effects of infrastructure contaminants to marine biota.

To achieve these aims, specific research objectives will be assessed. The objectives of this project are:

(A) To characterise the chemical and radiological constituents of contaminated material and determine the solubility of such material in seawater and a series of other solvents (e.g. dilute acid extractable),

(B) Determine the potential for bioaccumulation of contaminants by organisms by conducting laboratory exposure studies to determine chemical and radiological contaminant bioaccumulation and subsequent effects.

(C) Conduct bioaccumulation studies using mercury (organic and inorganic) radioisotope tracers to better define exposure pathways and fate of internalised mercury.

(D) Analyse data from laboratory studies and literature to develop or modify internationally-used environmental dose-response models.

(E) Contribute to a risk assessment framework of offshore petroleum operations-associated contaminants to the marine organisms.

Methodology

This research will utilise ANSTO's unique capabilities to handle, characterise, conduct animal exposures and dispose of waste associated with infrastructure residues. A combination of conventional analytical techniques (ICP-MS, XRF, particle size analysis etc.) and nuclear techniques (alpha and gamma spectrometry, neutron activation analysis, synchrotron x-ray fluorescence microscopy and x-ray adsorption spectroscopy) will be employed.

Objective A. Contaminants released to the environment from in-situ decommissioning of offshore infrastructure are often either in a speciation not readily bioavailable (i.e. as elemental mercury or mercuric sulfide) or are associated or bound in an insoluble corrosion matrix. To better understand the long-term fate of contaminants, and likely scenarios under which contaminants become bioavailable (e.g. release and methylation, NORM bioavailability), laboratory experiments will be conducted. Experiments will be designed to replicate field conditions of contaminant distribution and form and will examine the apparent bioavailable potential of those contaminants. Analytical elemental and radiometric techniques will be used to identify and classify the chemical composition and radioactivity levels of scale provided by the industry partner. Gamma and alpha spectrometry will be used to measure the uranium and thorium radioisotopes and their decay products. Due to environmental and operational differences between offshore assets, it is proposed that collection, analyses and characterisation will be conducted on several different sources of pipe scale from the industry partner. In addition, elemental analysis will determine the inorganic chemical characteristics of the pipe scale. This will include, but not be limited to, using acid digest, ICP-MS/OES to quantify inorganic elements and major ions in the scale. Mercury speciation analysis will be conducted in collaboration with CSIRO Land and Water and the Australian Synchrotron. Results will be compared to national guidelines for radiological protection and water & sediment quality guidelines for NORMs and inorganic constituents respectively. Standard leachate testing will characterise the elements and radionuclides when in contact with seawater (modified ASLP). This expands to measure the anticipated bioavailability of both NORM and metals to marine organisms, after ingestion using an acid-extractable leach test. The results of leach tests will be compared to "total" contaminant concentrations and to relevant environmental protection guidelines. Simplified biota dose modelling will be conducted with the ERICA Tool (if sufficient activities of NORMS are present to estimate the potential radiological dose to model marine organisms surrounding subsea infrastructure in a range of scenarios of infrastructure degradation (from non-degraded operational use to fully degraded pipeline mixing with surficial sediments). Results of the dose modelling will be compared to international benchmarks of radiological effects to marine organisms.

Objective B. To determine uptake and bioaccumulation of contaminants by marine organisms, several operational and environmental scenarios will be simulated. Where possible, commercially-relevant species found in the environment surrounding the industry partner's assets will be used. Marine organisms will be exposed to contaminants via suspension (e.g. for filter feeders) and direct dietary pathways (e.g. preparation of experimental food using infrastructure contaminants). Where significant leaching of contaminants into the dissolved phase has been determined from Objective A, soluble contaminant exposures will be conducted.

To determine the potential for contaminants associated with offshore decommissioned structures to be taken up (bioavailable) and accumulated by marine organisms, environmental scenarios will be simulated to address the following:

1. Understand contaminant flux/biotransformation and bioavailability in the environment.
2. Exposure pathway of how contaminants enter organisms.
3. How this bioaccumulation will affect key biochemical process.

Objective C. Mercury (organic and inorganic) radioisotope tracer techniques will be conducted in controlled laboratory conditions. This will allow us to accurately follow the bioaccumulation and loss rates (i.e. kinetics) of mercury in different forms from different sources (i.e. water or diet). We will also conduct organ dissections and use post-mortem imaging techniques to determine organ distribution of bioaccumulated mercury in different exposed organisms, as well as molecular assessments if bioaccumulation is significant.

This will assist in the interpretation of 'effects' assay results (Objective B) as well as eluding to the potential for food chain transfer to higher organisms. The bioaccumulation of NORMS will similarly be assessed using controlled laboratory condition to allow for an assessment of bioaccumulation, including uptake into organisms, elimination from organisms and fate of contaminants in terms of organ distribution.

Objective D. The data and findings from the laboratory studies will help provide evidence for a review and potential refinement of effect thresholds for species protection for contaminants occurring within the industry partner's offshore assets.

Objective E. Based on the outcomes of the previous objectives, a risk framework for the decommissioning of oil and gas infrastructure, more specifically offshore pipelines will be developed. Development of more accurate effect thresholds and environmental factors affecting bioavailability and bioaccumulation will be used to conduct more credible and realistic risk assessments for offshore decommissioned structures left in the marine environment.

Desired outcomes

In Australia and indeed globally, there has been little work in defining the specific chemical and radiological effects to organisms from scale materials in subsea oil and gas infrastructure, especially under scenarios of in-situ decommissioning. This study has several key outcomes:

1. Develop a data set of pipeline scale characteristics and solubility under several scenarios.
2. Develop a data set of pipeline scale-associated contaminant bioaccumulation parameters for several key marine fauna with the main focus on mercury.
3. Produce a preliminary data set of the effects of pipeline scale exposure to key marine fauna. This will contribute towards filling the current data gap on NORMs and mercury for the ecological protection of organisms in marine waters, specifically addressing toxicity thresholds for marine species which are used in the Australian and New Zealand Water and Sediment Quality Guidelines (see https://www.waterquality.gov.au/anz-guidelines). The assessment of any toxicological impact of closure scenarios will be discussed with the industry partner to ensure stakeholder acceptance and understanding.
4. Develop an ecological assessment framework to inform the planning of offshore petroleum infrastructure closure. It is expected that this framework could be applied to international jurisdictions outside Australia, especially where there are current gaps in environmental policies around offshore infrastructure closure.

A series of scientific publications are expected to be developed and a student thesis as part of the broader PhD research study.

Milestones and Timing

	2021				2022				2023			
Milestone	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
PhD Literature review												
Pipeline scale characterisation												
Scale bioaccumulation tests												
Mercury radiotracer experiments												
'Effects' assays												
Data interpretation and modelling												
Site visits (potential)												
Meetings with Industry Partner												
Draft Thesis and Publications												

Research Team

Dr. Tom Cresswell (ANSTO Senior Research Scientist) will be the lead coordinator for the project. Tom is an aquatic ecotoxicologist with expertise in live-animal radiotracing. He studies how pollution interacts with living organisms in freshwaters through to open oceans. Tom's position at ANSTO allows him to use nuclear techniques (radioisotope tracers) to very precisely study how quickly pollutants get into a living organism, where it goes within the tissues and then how quickly they are removed from the tissues if the source of pollution is removed or the animal moves to cleaner waters. Tom is currently working with several industry stakeholders to perform pipeline scale characterisation, solubility tests and bioavailability assessments.

Dr. Katherine Dafforn (Senior lecturer in Earth and Environmental Sciences, Macquarie University) will be the primary academic supervisor. Her work on the impacts of industrial contaminants has generated new knowledge to inform the development of advanced biomonitoring tools and management strategies to reduce impacts. She will bring her expertise as an ecotoxicologist and environmental scientist, capacity to successfully deliver impactful research and general enthusiasm in science communication that will be important in sharing the results of the project to relevant stakeholders. Her position at Macquarie University provides access to mentoring, collaborations and facilities that will be essential for this project.

Dr. Anthony Chariton (Senior Lecturer in Biological Sciences, Macquarie University) will be the secondary university supervisor. Anthony is one of the early pioneers of environmental DNA metabarcoding, with his research focusing on the development, application and integration of 'omic' technologies and traditional ecology for the monitoring and assessment of aquatic systems and it is this expertise that Anthony will bring to the project. Anthony has also been heavily involved in the derivation and updating of the ANZ water and sediment quality guidelines. Anthony will assist with the development and interpretation of the 'effects' assays.

Dr. Travis Elsdon (Marine Scientist, Chevron Energy Technology Pty Ltd) will be the primary industry contact and industry advisor. Travis has over 16 years' experience in marine sciences including environmental management and approvals, ecological monitoring and sampling and specific expertise in the oil and gas sector. Travis will advise on all aspects of experimental design, results interpretation and risk assessment framework development.

Dr. Simon Apte (Senior Senior Principal Research Scientist, CSIRO Land and Water). Simon has extensive experience with the analysis of trace metals and the links between trace metal speciation and aquatic organism bioavailability. Simon also has significant experience in understanding the fate of mercury cycling in aquatic environments. Simon will advise on all aspects of experimental design, results interpretation.

Other expertise in aquatic ecotoxicology and environmental quality guideline derivation from CSIRO Land and Water and other key ANSTO staff will be included at appropriate stages in the project. Other Chevron staff may also be involved in the project as required.

Student eligibility

The PhD student will have a 1st Class Hons. or equivalent in Environmental Toxicology, Chemistry, Biology or similar discipline. Experience in preparing and undertaking organism-contaminant exposure assays is beneficial but not crucial. Radiation safety training and radiation dose modelling to organism software/techniques will be provided by ANSTO.

Funding

Prospective PhD students will be invited to apply for a Macquarie University Research Training Program (RTP) scholarship, which if successful, will then be eligible to apply for an ANSTO top-up scholarship ($7,500 per year). The project includes funding for consumables, analyses, travel (conferences and partner meetings) and open-access journal publication fees.

Expressions of Interest

If you are interested in this project, please send the following to the email address below:

1. CV/Resume
2. A statement outlining your prior experience in environmental science and why you are interested in this project (max 200 words).

The prospective student will be required to submit an application for a PhD program to Macquarie University by October 2020.

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