Marine Pollution Bulletin 129 (2018) 241–244

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Note

Offshore pipeline decommissioning: Scale and context

Sally Rouse[a,b,*], Peter Hayes[b], Ian M. Davies[b], Thomas A. Wilding[a]

[a] Scottish Association for Marine Science, Oban, Argyll PA37 1QA, UK
[b] Marine Scotland Science, Marine Laboratory, 375 Victoria Road, Aberdeen AB24 2TZ, UK

ARTICLE INFO

Keywords:
Marine spatial planning
Decommissioning
Pipelines
Oil and gas
Fishing
North Sea

ABSTRACT

The spatial extent of human activities must be understood for consistent and proportionate regulation, and effective marine planning. Redundant offshore pipelines can be removed or left *in situ*, but data on the footprint of these options are not readily available. The extents of three North Sea *in situ* decommissioning scenarios are presented. Leaving pipelines *in situ* would occupy < 0.01% (12.3 km^2) of UK waters, and this was similar to, or smaller than, other regulated activities (*e.g.* aggregate extraction). Adding armouring to large pipelines occupied up to 95 km^2, while creating fisheries exclusion zones occupied up to 1119 km^2. Removal of pipelines > 30″ would be required to regain 50% or more of the seabed currently occupied. At present, the technology to remove pipelines > 16″ safely and cost-efficiently is untested for large-scale decommissioning projects. The summaries presented inform the debate over the significance of decommissioning, and the regional consequences of different options.

1. Introduction

To exploit offshore oil and gas (O&G) reserves, extensive man-made infrastructure has been deployed onto the seabed, including platforms, wellheads and pipelines. The term ‘pipeline’, in an oil and gas context, is used to refer to umbilicals (for transporting chemicals or hydraulic fluids) and larger diameter flowlines and trunklines (which transport oil or gas). Databases on pipelines, *e.g.* UK Oil and Gas Data, (CDA, 2013), will also typically include oil and gas related mooring lines, anchor chains and power cables. Pipelines range in diameter from 2 to 44 in. and are generally constructed from steel, often with concrete or polymer external coatings (Oil and Gas UK, 2013). Pipelines are classified as ‘surface laid’ (*i.e.* resting on top of the seabed) or ‘trenched’ (laid within a trench that is back filled (naturally or artificially) or left open) (Oil and Gas UK, 2013).

For the majority of oil exploiting nations, the deployment and subsequent decommissioning of O&G infrastructure is heavily regulated. For the 15 European countries that are contracting parties to the OSPAR agreement, the 98/3 Decision requires that platforms are returned to land for onshore disposal after production has ceased (DECC, 2011; OSPAR, 1998). The 98/3 Decision includes a derogation facility, allowing operators to apply to leave platforms meeting certain criteria on weight (> 10,000 tonnes) or construction material (concrete) *in situ* (DECC, 2011; OSPAR, 1998). The 98/3 Decision does not cover pipelines and individual nations are able to establish their own pipeline decommissioning policy. Current UK guidelines state that operators should seek to remove pipelines, unless they are sufficiently buried (> 0.6 m) or if existing technology is not suitable to remove that particular type of pipeline, *e.g.* for large diameter trunklines (DECC, 2011). In the Norwegian and Dutch sectors of the North Sea, pipelines will typically be left *in situ* after cessation of production, with removal, burial or protective coverings applied to specific pipeline sections following an individual assessment of the risk of obstruction and/or hazard to fishing (EBN, 2016; NPD, 2010).

The commercial fishing industry is a major stakeholder in pipeline decommissioning decisions and the impacts of potential decommissioning strategies on fisheries (as well as other users of the sea) must be considered during the consultation stage. The presence of *in situ* decommissioned pipelines may pose a snagging hazard for fishing gear, and physical contact between fishing gear and pipelines may cause pipeline damage (de Groot, 1982; Jiexin et al., 2013). Armouring can be added to *in situ* decommissioned pipelines to mitigate the snagging hazards and/or protect the remaining pipeline from fishing gear damage (Oil and Gas UK, 2013). The most common form of armour is ‘rock dump’, which is graded, crushed rock and/or gravel placed on top of, and around, pipeline sections. The addition of armouring, with a smooth 1 in 3 profile, is a standard industry practice to reduce the risk of fishing gear snagging on subsea hazards (Oil and Gas UK, 2013; Pidduck et al., 2017).

For most European oil producing nations, state governments are liable for a significant proportion of decommissioning costs (up to 70%) and, as such, decisions regarding pipeline decommissioning policy will

* Corresponding author at: Scottish Association for Marine Science, Oban, Argyll PA37 1QA, UK.
E-mail addresses: Sally.rouse@sams.ac.uk (S. Rouse), Peter.hayes@gov.scot (P. Hayes), Ian.davies@gov.scot (I.M. Davies), tom.wilding@sams.ac.uk (T.A. Wilding).

https://doi.org/10.1016/j.marpolbul.2018.02.041
Received 18 July 2017; Received in revised form 12 February 2018; Accepted 22 February 2018

have significant implications for tax-payers (Ekins et al., 2006; Willigers and Hausken, 2013). The regulation of any activity in the marine environment, including the decommissioning of oil and gas infrastructure, should seek to be both consistent and proportionate to the potential impact that the activity will have on the environment and other sea users (Peel and Lloyd, 2008; Wright, 2014b). Additionally, EU guidance for maritime spatial planning advocates a transparent decision-making process with clear justification for policy decisions (Flannery and Ó Cinnéide, 2012). To these ends, it is necessary to understand the scale of pipeline decommissioning, under various scenarios, especially given the cost implications and potential safety risks of *in situ* infrastructure to fishers (Oil and Gas UK, 2013). Alternative decommissioning scenarios could include leaving a greater number of pipelines *in situ*, with or without rock dump, or a move towards removing larger diameter pipelines as technology progresses. To set pipeline decommissioning scenarios in an appropriate context, it is also necessary to understand the scale of other marine industries (Strain et al., 2006).

The aim of this study was to quantify the spatial extent of pipeline decommissioning scenarios on the United Kingdom Continental Shelf (UKCS) and the 'worst-case' spatial extent of potential mitigation options in relation fishing. The results will inform the debate over the significance of pipeline decommissioning to the environment and the fishing industry, and the consequences of different decommissioning options. These data will contribute to the evidence-base required by policy makers and thus ensure effective marine spatial planning.

2. Methods

Data on the location and attributes of pipelines were obtained from the Oil and Gas UK Common Data Access (CDA, 2013) and contained information on the pipeline type (including umbilicals, mooring lines and anchor chains) and the diameter of the pipeline. Data on the identity and location of surface laid pipelines are not readily available. The only available estimate suggests that approximately 13% of UK pipelines are surface laid (PARLOC, 2012). The location, diameter and length of the surface laid pipelines are, however, unknown, preventing the accurate calculation of areas. It is assumed that the data on UKCS activities represents the entire 'population' for the UKCS (rather than a sample) and thus results are presented as descriptive statistics rather than applying inferential statistics.

2.1. Decommissioning scenarios

The areas of seabed occupied (spatial footprint) by four decommissioning scenarios were quantified. For each decommissioning scenario, two figures are presented to account for the uncertainty regarding whether pipelines are surface laid or not. The two figures are a 'worst-case' scenario, assuming that all pipelines are surface laid, and a '13% assumption', assuming that the proportion of pipelines that are surface laid is uniform across pipelines of all diameters and lengths.

The scenarios were:

(1) Leaving pipelines *in situ* with no intervention.
(2) Adding armouring (rock dump) to large pipelines (> 16 in.) left *in situ* to mitigate the risks from fisheries interaction (in terms of snagging hazards and pipeline damage).
(3) Establishing a fisheries exclusion area ('buffer zone') around large pipelines left *in situ*, as an alternative form of mitigation.
(4) Removal of large pipelines.

It is generally assumed that any surface laid umbilicals, mooring lines, anchor chains and small diameter pipelines (below 16 in., ~0.4 m) can be easily removed. The only technology solution presently available to remove larger pipelines (> 16 in.) involves subsea cutting of the pipeline into smaller sections which are then removed individually using lifting gear (Oil and Gas UK, 2013). Subsea cutting is a time consuming and costly process, with higher safety risks to personnel than alternative pipeline removal methods (Oil and Gas UK, 2013). The safety and efficiency of pipeline removal *via* cut and lift remains untested for large scale decommissioning projects (Oil and Gas UK, 2013). The total lengths of pipeline in each of the following five categories were therefore calculated: pipelines < 16 in., pipelines > 16 in., umbilicals, mooring lines and anchor chains. The lengths of pipeline were multiplied by the diameter to give an estimate of area on the seabed (duplicated areas, where pipelines overlap, were excluded to give only the outline area). These figures represent estimates of the area of the UKCS that would be occupied if pipelines were decommissioned *in situ* (scenario 1).

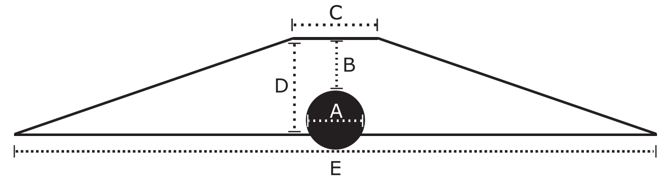

Fig. 1. Schematic of generic dimensions of rock dump with a 1 in 3 slope covering a 26 inch pipeline (shaded circle). Dimensions: pipeline diameter (a) = 0.7 m, height of rock dump above pipe (b) = 0.6 m, width of rock dump above pipe (c) = 1 m, total height of rock dump (d) = 1.1 m, (e) = width of rock dump on seabed = 7.6 m.

For the rock dump scenario, the footprint and volume of deposits were calculated, assuming that only large pipelines (> 16 in.) would be left *in situ* and rock dumped. The average diameter of large pipelines in the North Sea (26 in.) was used to calculate the area of seabed covered, and the cross sectional area of rock dump required to cover all pipelines > 16 in., using the recommended 1 in 3 slope (Ripoll et al., 2014) (Fig. 1). The volume of rock that would be required was calculated assuming 50% porosity and a density of 2.7 tonnes/m^3 (Smithson, 1971).

For the buffer zone scenario, the total area around pipelines > 16 in., extending 50 m either side, was calculated as a potential fisheries exclusion zone. A 50 m exclusion zone was selected as an example of the area that might be avoided by fishing vessels to prevent snagging on degraded pipelines.

The spatial extent of the fourth decommissioning scenario represents the area of seabed that would be regained if technology improvements allowed for the removal of larger diameter pipelines. The areas occupied by pipelines between 16 and 20 in. and between 20 and 24 in. were quantified. The minimum pipeline diameter that must be removed in order to regain at least 50% of the seabed currently occupied by pipelines was also calculated to provide an example of required technology improvements.

2.2. Spatial extent of other UKCS activities

The total area of other UKCS activities was calculated to provide scale and context for the decommissioning scenarios. Activities that were not considered (due to data limitations) were wave and tidal energy and military seabed activity (Brooks, 2013). Spatial data for other UKCS uses and activities were obtained from the sources listed in Table 2. In addition, the tracks of UK demersal fishing vessels > 15 m in 2015 were obtained from Vessel Monitoring System data according to the methods of Rouse et al. (2017). To estimate the swept areas (area covered by fishing gear) of demersal fishing, tracks were multiplied by an assumed gear width of 16.5 m for dredgers, 18 m for beam trawlers and 80 m for otter trawlers (average of *Nephrops* and other trawlers) (Gerritsen et al., 2013). The total footprint was calculated by summing the swept areas, with duplicated areas, where tracks overlapped, removed. Wrecks were assigned a nominal area of 962 m^2, based on the average (available) width and length measurements made by Eastwood et al. (2007). For offshore wind, the total MW capacity of operational, consented, planned and pre-planning turbines was calculated and