THE RADIOLOGICAL IMPACT OF OIL AND GAS INDUSTRY DISCHARGES ON THE UK POPULATION

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1 ABSTRACT

This paper describes a study undertaken to estimate doses to members of the public from the disposal to sea of scale, sludge and other wastes containing enhanced levels of naturally occurring radionuclides from UK offshore oil and gas platforms. One of the difficulties in determining these doses is the lack of detailed source term information. There are currently approximately 80 UK offshore platforms that dispose of scale and other wastes under authorisations granted, under the terms of the Radioactive Substances Act 1993, by the Scottish Environment Protection Agency or the Environment Agency. These authorisations stipulate maximum quantities of radionuclides that can be released from the platform on an annual basis. However, discharges from these and other platforms are also carried out under the terms of the Radioactive Substances (Phosphatic Substances, Rare Earths etc) Exemption Order. This allows the disposal of unlimited quantities of material with radionuclide concentrations below defined levels. There is no requirement for records to be kept of disposals made under the terms of this exemption order. As actual release inventories were not available, estimates were made based on authorisation limits and additional information on waste disposal from offshore platforms. The transport of radionuclides in the marine environment and the resulting doses were determined using BIOS, a compartmental biosphere model developed at NRPB.

The predicted peak individual dose to a typical member of the hypothetical critical group for releases at the maximum authorised limit from offshore platforms is less than 0.1 μSv y^{-1}.

2 INTRODUCTION

Oil production in the UK is predominantly in the Scottish waters, whereas gas production is almost entirely off the East Coast of England, there are also a few oil and gas fields in Liverpool and Morecambe Bays. There are currently approximately 230 active UK offshore platforms, of which 80 have authorisations for discharges of radioactive wastes.

The oil and gas production process results in the release of naturally occurring radionuclides to the environment. The process of the formation of oil and gas in the earth's crust often results in elevated concentrations of ^{238}U and ^{232}Th within surrounding rocks, as uranium and thorium preferentially concentrate in rocks containing organic matter. Oil and gas production processes mobilise naturally occurring radionuclides, which are either deposited in sludges or scales in production, treatment and transport facilities or appear in produced water. The radionuclides that are primarily mobilised and appear in sludges and scales are isotopes of radium, principally ^{226}Ra and ^{228}Ra, and their daughters. Soft scales, sludges and sands from UK platforms are macerated to fine particles and then mixed with produced water and seawater and then discharged under the sea level from the side of the platform. Depending upon the radionuclide concentrations in the waste, disposals take place either under the terms of authorisations granted, under the terms of the Radioactive Substances Act 1993(1), by the Scottish Environment Protection Agency or the Environment Agency, or under the terms of the Radioactive Substances (Phosphatic Substances, Rare Earths etc) Exemption Order(2).

A study has been undertaken to assess the radiological impact of these disposals from UK offshore oil and gas platforms. The methodology used and the preliminary results obtained are presented here.

3 METHODOLOGY

The exposed group receiving the highest doses from releases from offshore platforms, the hypothetical critical group, is assumed to consist of individuals consuming large quantities of seafood (fish, crustacea and molluscs) caught in the regions around the platforms. Fishermen in these areas were chosen to represent this group as it is anticipated that they would consume large quantities of seafood and would also receive doses from the inhalation of sea spray and external irradiation from contaminated fishing gear. For safety reasons fishing in close proximity to platforms is not permitted. It is also unlikely that sufficient quantities of fish could be caught in the small areas immediately surrounding a platform. For these reasons, it was deemed appropriate to consider small regions where, in general, a number of platforms are grouped together in small clusters, and consider the consequences of discharges into each of these “local boxes”. The characteristics of the local boxes are described below, in Section 2.1. The release inventories considered are discussed in Section 2.2. The transport of radionuclides in the marine environment and the resulting doses were determined using BIOS(3), a compartmental biosphere model developed at NRPB. The version of BIOS used includes a 34 box ocean model. In the absence of site specific information generic critical group ingestion rates for seafood representative of UK coastal communities were used(4).

3.1 Local Boxes

The DTI Oil and Gas Activity Map(5) gives the locations of all exploration and production sites in the UK, both on and offshore. There is also an index of the offshore oil fields containing details of the quadrant and block each field is located in. The map and index were used to establish “local boxes” (areas where a number of fields or platforms are grouped together in small clusters). A total of 16 local boxes were identified.

The area of each box was determined using the DTI Oil and Gas Activity Map (5) as a guide to establish the approximate length and width of each region. The mean depth of each box was determined using data from the Scottish Petroleum Annual 1985(6), where detailed information about all platforms dating back to that year is contained, and the Elf Exploration UK plc Facts and Figures Folder(7), which contains platform details for all Elf maintained and co-owned platforms. The multiplication of the mean depth by the calculated box area gave the volume of the local box.

BIOS requires input and output fluxes for local boxes, these were determined using information on currents(8,9,10).

3.2 Release Inventories

There are currently around 230 active UK offshore platforms. Approximately 80 of these dispose of scale and other wastes under authorisations granted, under the terms of the Radioactive Substances Act 1993(1), by the Scottish Environment Protection Agency or the Environment Agency. These authorisations stipulate maximum quantities of radionuclides that can be released from the platform on an annual basis. Maximum disposal authorisations range between 1 and 45 GBq per year. The authorisations also define the conditions under which the disposals take place. The waste must be in the form of a suspension, and not more than 2% by weight of the material contained in suspension may have a diameter greater than 1 millimetre. The minimum distance below the surface that a discharge can be made is also prescribed. The authorisations also require that records be kept of disposals made under it. In order to determine the radiological impact of authorised releases two source terms were considered, releases at the maximum disposal limit for one year and thirty years. Thirty years was chosen to represent platform lifetime.

Discharges from all platforms can also be carried out under the terms of the Radioactive Substances (Phosphatic Substances, Rare Earths etc) Exemption Order(2). This allows the disposal of unlimited quantities of material with radionuclide concentrations below defined levels. For radium the maximum concentration is 14.8 Bq g^{-1}. There is no requirement for records to be kept of disposals made under the terms of this exemption order. For this reason there is very little information available on quantities of radionuclides discharged under the Exemption Order. Some information suggests that such discharges are made fairly regularly(12), with some of the older platforms discharging daily. A mass of 30 tonnes was suggested as a normal quantity to be discharged at any one time(12). In order to investigate the radiological impact of discharges made under the Exemption Order three hypothetical release inventories were considered. In each case it was assumed that 30 tonnes was disposed at any one time. For the first release inventory, EO1, it was assumed that such a discharge occurred once a year. For the second release inventory, EO12, it was assumed that such a discharge occurred monthly. The final release inventory, EO365, assumed daily discharges. In the absence of information on radionuclide concentrations in the waste it was pessimistically assumed that the concentrations were the maximum allowed under the terms of the Exemption Order, ie the total activity concentration of all radium isotopes present is14.8 Bq g^{-1}(2).

The five release inventories considered for each local box are summarised in Table 1. Note that platforms in local boxes 2 to 5 and 9 do not have disposal authorisations.

Table 1: Release Inventories for each local box

		Release Inventories[1] (GBq y^{-1})			
Local Box Number	Number of Platforms	Authorisation Limit	Exemption Order (EO365)	Exemption Order (EO12)	Exemption Order (EO1)
1	57	30	$4.3\ 10^4$	$1.4\ 10^3$	$1.2\ 10^2$
2	12	-	$9.0\ 10^3$	$3.0\ 10^2$	$2.5\ 10^1$
3	10	-	$7.7\ 10^3$	$2.5\ 10^2$	$2.1\ 10^1$
4	4	-	$3.0\ 10^3$	$1.0\ 10^2$	$8.3\ 10^0$
5	3	-	$2.3\ 10^3$	$7.3\ 10^1$	$6.3\ 10^0$
6	8	36	$6.0\ 10^3$	$2.0\ 10^2$	$1.7\ 10^1$
7	4	60	$3.0\ 10^3$	$1.0\ 10^2$	$8.3\ 10^0$
8	33	10	$2.5\ 10^4$	$8.3\ 10^2$	$7.0\ 10^1$
9	8	-	$6.0\ 10^3$	$2.0\ 10^2$	$1.7\ 10^1$
10	20	91	$1.5\ 10^4$	$5.0\ 10^2$	$4.0\ 10^1$
11	3	11	$2.3\ 10^3$	$7.3\ 10^1$	$6.3\ 10^0$
12	25	75	$1.9\ 10^4$	$6.3\ 10^2$	$5.3\ 10^1$
13	9	60	$6.7\ 10^3$	$2.2\ 10^2$	$1.9\ 10^1$
14	1	20	$7.7\ 10^2$	$2.5\ 10^1$	$2.1\ 10^0$
15	28	152	$2.3\ 10^4$	$7.0\ 10^2$	$5.7\ 10^1$
16	2	20	$1.5\ 10^3$	$5.0\ 10^1$	$4.0\ 10^0$

Note:

1. Total discharge inventory. Discharges of each radionuclide in the ^{226}Ra and ^{228}Ra decay chains were determined assuming the activity concentrations of ^{226}Ra and ^{228}Ra were equal and the short-lived daughters are in equilibrium; using the following formula:
   Total activity = $6\times{}^{226}Ra$ activity + $8\times{}^{228}Ra$ activity(12).

4 RESULTS

Predicted peak annual individual doses are presented in Table 2. Peak individual doses to a typical member of the hypothetical critical group for sea discharges at the authorisation limit for one year to each local box, ranged from approximately 4 nSv y^{-1} to 78 nSv y^{-1}. If releases at the authorisation limit continued for 30 years, it is predicted that the doses would increase by up to 40%, with an overall range of about 6 nSv y^{-1} to 78 nSv y^{-1}. It has been suggested (13) that only 10% of the current discharge limits are being utilised by the majority of the platforms, although some platforms in 1999 discharged well in excess of 50% of the activity limit. On this basis it is unlikely that discharges to each local box occur at the maximum authorised limit. For this reason the predicted doses given here are expected to be overestimates of the actual doses received from discharges carried out under authorisation. Doses to typical members of the UK population are expected to be lower still.

Predicted peak individual doses from sea discharges to each local box of release inventory EO1 (1 single release of 30 tonnes of scale waste per year from each platform), ranged from 2 nSv y^{-1} to 0.2 μSv y^{-1}. Individual doses for release inventory EO12 (360 tonnes of scale waste per year from each platform) were, as expected, a factor of 12 higher, ranging from 25 nSv y^{-1} to 2 μSv y^{-1}. Individual doses for release inventory EO365 (10950 tonnes of scale waste per year from each platform) were, similarly, a factor of 365 times higher than those for EO1, with a range of approximately 0.8 μSv y^{-1} to 70 μSv y^{-1}. The highest doses from the Exemption Order release inventories were for releases into the shallower waters of Liverpool and Morecambe Bay (local boxes 4 and 5). The water volumes and fluxes are much lower in these local boxes than other local boxes, resulting in higher activity concentrations in these regions.

For all source terms and local boxes the dominant exposure pathway was the ingestion of sea fish, crustacea and molluscs, accounting for 99% of the total dose, with up to 70% of the total dose due to the consumption of sea fish. The dominant radionuclide was ^{226}Ra.

5 DISCUSSION

IAEA have concluded (14) that a level of dose of some tens of microsieverts a year could reasonably be regarded as trivial by regulatory authorities. The maximum predicted doses to members of the public from authorised discharges are less than 0.1 μSv y^{-1}, which is clearly significantly lower than the IAEA "trivial" level. These predicted doses are expected to be overestimates of the actual doses received for a number of reasons. The principal reason is that the assumption that individuals consume large quantities of seafood caught from one small region is likely to be pessimistic. The actual releases are also expected to be below the authorisation limit. Doses to typical members of the UK population will be lower still.

The maximum predicted doses to members of the public from discharges under the Exemption Order range from 2 nSvy^{-1} to 70 μSvy^{-1}, depending upon the release inventory assumed and the local box into which the release occurs. The majority of doses are below the IAEA “trivial” level of some tens of microsieverts. Doses above this level are only estimated for the highest Exemption Order release inventory, EO365, to four of the sixteen local boxes. It is likely that all these doses are overestimates as the assumption that individuals consume large quantities of seafood caught from one small region is likely to be pessimistic. It should also be stressed that these release inventories are preliminary estimates only. Further studies will be undertaken to develop more robust Exemption Order release inventories.

Table 2: Peak annual individual doses for releases to each local box of a number of release inventories

	Individual dose (μSv y^{-1})				
Local Box Number	Exemption Order EO1	Exemption Order EO12	Exemption Order EO365	Authorisation limit for 1 year	Authorisation limit for 30 years
1	1.2 10^{-1}	1.4	4.3 10^{1}	2.9 10^{-2}	3.0 10^{-2}
2	1.1 10^{-1}	1.3	4.0 10^{1}		
3	1.6 10^{-2}	1.9 10^{-1}	5.7		
4	1.9 10^{-1}	2.3	7.0 10^{1}		
5	1.5 10^{-1}	1.8	5.3 10^{1}		
6	1.6 10^{-2}	2.0 10^{-1}	6.0	3.6 10^{-2}	4.1 10^{-2}
7	2.1 10^{-3}	2.5 10^{-2}	7.7 10^{-1}	1.5 10^{-2}	1.7 10^{-2}
8	2.7 10^{-2}	3.2 10^{-1}	1.0 10^{1}	3.9 10^{-3}	5.6 10^{-3}
9	1.0 10^{-1}	1.2	3.7 10^{1}		
10	9.7 10^{-3}	1.2 10^{-1}	3.7	2.2 10^{-2}	2.4 10^{-2}
11	2.9 10^{-3}	3.7 10^{-2}	1.1	5.2 10^{-3}	5.4 10^{-3}
12	4.0 10^{-2}	4.7 10^{-1}	1.4 10^{1}	5.7 10^{-2}	5.9 10^{-2}
13	1.3 10^{-2}	1.6 10^{-1}	5.0	4.2 10^{-2}	4.4 10^{-2}
14	8.0 10^{-3}	9.7 10^{-2}	2.9	7.8 10^{-2}	7.8 10^{-2}
15	1.9 10^{-2}	2.3 10^{-1}	7.3	5.0 10^{-2}	5.4 10^{-2}
16	3.7 10^{-3}	4.3 10^{-2}	1.4	1.8 10^{-2}	1.8 10^{-2}

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