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Environment report RL05/06

Dose assessments in relation to disposal at sea under the London Convention 1972: judging *de minimis* radioactivity

For Defra
Project AA005

Environment Report RL 05/06

Dose assessments in relation to disposal at sea under the London Convention 1972: judging *de minimis* radioactivity

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Executive summary

The UK government is a signatory to the London Convention (1972) that prohibits the disposal of radioactive material at sea unless it fulfils exemption criteria developed by the International Atomic Energy Agency (IAEA). If both the following radiological criteria are satisfied:

(i) the effective dose expected to be incurred by any member of the public or ships crew is of the order of 10 μSv or less in a year;

(ii) the collective effective dose to the public or ships crew is not more than 1 man Sv per annum

then the material is deemed to contain *de minimis* levels of radioactivity and may be disposed at sea pursuant to it fulfilling all the other provisions under the Convention. The individual dose criteria are placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 μSv/a.

In England and Wales, Defra continues to issue licences to operators for the disposal at sea of dredge material. However, many ports can be affected by the authorised discharge of low-level radioactive wastes from nuclear establishments around the coastline of the UK; both current and historical. The objective of this project was to assess whether disposal of dredging material from ports in England & Wales fulfil the radiological criteria. Dredging to obtain marine aggregates, was excluded from the remit of this project.

The coastline around England & Wales was divided into nine separate regions, based on the previous Sea Fisheries Inspectorate (SFI, now known as the Marine Fisheries Agency or MFA) districts. A review of existing data was carried out

concerning the sources and specific activity of radionuclides in sediment for these individual regions. Additional information was also collated to enable the estimation of individual and collective doses, resulting from exposure to dredge material. Dose calculations were carried out by following the radiological assessment guidelines issued by the IAEA, in 2003, to provide conservative estimates.

The greatest radioactive contamination occurs at the small ports along the Cumbrian coastline (Region 1), to the north of the BNF Sellafield reprocessing plant. A case study of a recent operation at Whitehaven, the most affected port, indicated that the predicted dose to crew (~8 μSv) was close to 10 μSv. Results from subsequent field measurements indicated the actual dose might have been slightly greater than 10 μSv, although the error associated with the derived value was high. It is recommended that specific individual assessments continue for all Cumbrian ports.

Information concerning radionuclide activity in sediments from our major ports is sparse and the gaps have only been partially filled by the work reported here. Application of the available data indicated that, the *de minimis* criteria were met in the eight regions outside the northern Irish Sea. These generic radiological assessments will allow managers to reach an early decision in the future, as to whether the provisions of the London Convention are fulfilled, without the need for more detailed individual assessments. It is, nevertheless, recommended that the existing approach of appropriate measurements of radionuclide sediment activity continue for ports outside the Irish Sea, concomitant with measurements of other contaminants, to build up a more robust database.

1. INTRODUCTION

1.1 Background

In 1993 the UK accepted a global ban on the sea disposal of all radioactive wastes, under the London Convention 1972 (The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972), superseding the ban which applied only to high level radioactive waste. However, all materials, including natural and inert materials, contain natural radionuclides. In addition many are contaminated with artificial radionuclides from anthropogenic sources, such as global fallout due to past atmospheric testing of nuclear weapons. Therefore, the contracting parties to the London Convention recognised the need to develop definitions and guidelines whereby candidate materials (those wastes or other matter not otherwise prohibited from disposal at sea in accordance with annex I to the Convention) containing *de minimis* levels of radionuclides could be disposed of pursuant to the provisions of this Convention.

In England and Wales, Defra issues licences to ports, harbours and marinas for the disposal of material at sea (principally the disposal of dredged material) under Part II of the Food and Environment Protection Act, 1985 (United Kingdom – Parliament, 1985). The respective licensing authorities in Scotland and Northern Ireland are the Fisheries Research Services (on behalf of the Scottish Executive, Environment and Rural Affairs Department) and the Environment Heritage Service (on behalf of the Department of the Environment Northern Ireland). This activity is authorised because dredging and sea disposal of dredged material are essential to shipping and navigation in the UK. Without adequate depths within our ports, harbours and marinas, shipping, trade and recreational boating would be severely

restricted. A small number of licences are also issued for disposal of other materials including fish waste (CEFAS, 2005a). Dredging to obtain marine aggregates, was excluded from the remit of this project. Given that almost all materials, including dredge deposits and fish waste, are naturally radioactive, it is permissible to dispose them at sea provided they fulfil the necessary exemption (*de minimis*) criteria.

1.2 Basis for the assessment of *de minimis* radioactivity

The current system of radiological protection is based entirely on the protection of human health. This has been developed over many decades and there are now internationally accepted guidelines and standards for national radiation protection authorities. There is currently no internationally-accepted basis for the protection of the environment, including flora and fauna, from the effects of radiation (Pentreath, 2004). Accordingly, the IAEA advice with regard to the *de minimis* issue is based on the protection of human health.

Materials are deemed to contain *de minimis* levels of radioactivity and may be disposed at sea, subject to their fulfilling all the other provisions of the Convention, provided both the following radiological criteria are satisfied:

(i) the effective dose expected to be incurred by any member of the public or ships crew is of the order of 10 μSv or less in a year;

(ii) the collective effective dose to the public or ships crew is not more than 1 man Sv per annum

1.3 Development of the *de minimis* concept under the London Convention 1972

The UK government ratified the London Convention 1972 on the 'Prevention of marine pollution by dumping of wastes and other matter' in November 1975. Annex I of the Convention banned the disposal of high-level radioactive waste at sea. However, all materials, including natural and inert materials, contain natural radionuclides and are frequently contaminated with artificial radionuclides from such anthropogenic sources as fallout due to past atmospheric nuclear testing. Recognising this, the first Consultative Meeting of the Convention in 1976 requested the IAEA to develop the concept of '*de minimis*' levels of radioactivity and a similar request was made in 1985. However, these requests did not lead to an agreed definition or approach to defining *de minimis*.

Paragraph 6 of Annex I of the Convention, as amended in 1993, prohibits the disposal at sea of 'Radioactive wastes and other radioactive matter' but it also states that:

> "Paragraph 6 does not apply to wastes or other materials (e.g. sewage sludge and dredged material) containing *de minimis* (exempt) levels of radioactivity as defined by the IAEA and adopted by the Contracting Parties. Unless otherwise prohibited by Annex I, such wastes shall be subject to the provisions of Annexes II and III as appropriate."

In adopting the resolution that prohibited the disposal at sea of radioactive waste via the amendment of Annex I, the Consultative Meeting noted its earlier request to

the IAEA "to develop quantitative limits for '*de minimis*' (exempt) levels of radioactivity" for the purposes of the London Convention.

In 1997 the Consultative Meeting was asked by the IAEA to review its request concerning the concept of *de minimis*, with a view to clarifying the task required of the IAEA. The revised task was defined as:

> "The meeting agreed that the IAEA should be requested to provide guidance for making judgements on whether materials planned to be dumped could be exempted from radiological control or whether a specific assessment was needed. The IAEA would then further be requested to provide guidance to national authorities responsible for conducting specific assessments."

The IAEA responded to the first part of the request by providing the London Convention 20th Consultative Meeting in 1998 with a draft report titled 'Application of radiological exclusion and exemption principles to sea disposal'. Following comments from that meeting, the IAEA published the revised document IAEA-TECDOC-1068 (IAEA, 1999) in March 1999 for consideration by the 21st Consultative Meeting in October 1999.

The London Convention 20th Consultative Meeting considered that the IAEA advice required some clarification for an audience that was likely to be unfamiliar with the terminology used in the field of radiological protection. They convened an inter-sessional Ad Hoc meeting of experts in May 1999 to provide that clarification and the resulting document was subsequently adopted by the 21st London Convention Consultative Meeting in October 1999 as the 'Guidelines for the application of the *de minimis* concept under the London Convention 1972' (London

Convention, 1999). This document contains a stepwise evaluation procedure to assess candidate materials to determine if they contain *de minimis* levels of radioactivity or if a specific assessment is required. This evaluation procedure is intended to be implemented through judgements based on available information regarding the provenance of candidate materials and sediments in the receiving marine environment, specifically at the dump-site. The questions posed at each of the first five steps are designed to be answered without the need for direct measurements of radionuclides in either the candidate material or the marine environment. In cases when there is insufficient existing information on which to base such judgements a specific assessment would be required. A summary of the stepwise evaluation procedure, to assess whether the exemption criteria are met, is given in Fig. 1.

Figure 1 - Stepwise evaluation procedure to assess whether materials may be disposed at sea in the context of the London Convention 1972 (taken from IAEA, 2003).

Step 1: Candidate material
1. Are the proposed materials eligible for dumping under the provisions of the London Convention 1972?
2. If NO, the material is not allowed to be dumped and no further consideration is warranted.
3. If YES, go to Step 2.

Step 2: Initial screen for sources of contamination
1. Is there reason to believe that the candidate material contains anything other than unmodified natural radionuclides at background comparable with that in the receiving environment and artificial radionuclides derived from global fallout?
2. If NO, the materials are *de minimis*.
3. If YES, go to Step 3.

Step 3: Assessment of additional causes/sources
1. What are the likely additional causes/sources contributing to the radioactivity in the materials?
2. If only unmodified natural causes/sources, go to Step 4.
3. If only anthropogenic causes/sources, go to Step 5.
4. If both anthropogenic and natural causes/sources, go to Step 5.

Step 4: Natural causes/sources
1. If the material were to be dumped, would it substantially increase radioactivity at the dumpsite?
2. If NO, the materials are *de minimis*.
3. If YES, go to Step 6.

Step 5: Anthropogenic causes/sources
1. Were the likely anthropogenic causes/sources part of exempted or cleared practices or excluded exposures?
2. If NO, go to Step 6
3. If YES, were the marine environmental exposure pathways considered by the national radiation protection authority and are these suitable to an assessment of the proposed dumping operation?
3.1. If YES, the materials are *de minimis*.
3.2. If NO, go to Step 6.

Step 6: Specific assessment
Materials not determined to be *de minimis* through the evaluation in Steps 1–5 above could also be determined to be *de minimis* by the application of a specific assessment if:
(i) the effective dose expected to be incurred by any member of the public or ships crew is 10 μSv or less in a year and;
(ii) the collective effective dose to the public or ships crew is not more than 1 man Sv per annum

Following the adoption of IAEA-TECDOC-1068 and the London Convention Guidelines referred to above, the 21st Consultative Meeting requested the IAEA to prepare additional guidance on conducting specific assessments to determine whether candidate materials for disposal at sea contained *de minimis* levels of radioactivity. After several years work, the IAEA provided a report to the London Convention Consultative Meeting in 2003 titled 'Determining the suitability of materials for disposal at sea under the London Convention 1972: A radiological assessment procedure' (IAEA, 2003) in fulfilment of the request from the London Convention. This report addressed Step 6 of the Stepwise Evaluation Procedure. The 25th London Convention Consultative Meeting in 2003 adopted the guidance from the IAEA.

The specific assessment process requires estimates of the quantity of the candidate material to be disposed of, its origin and the activity concentrations of the constituent radionuclides. The guidance provided by the IAEA is, however, pragmatic and allows for the nature and extent of a specific assessment to be determined in accordance with existing knowledge. Therefore, sediments containing only relatively minor amounts of artificial radionuclides need not be subjected to an unnecessarily detailed assessment process. Provided sufficient information is available to allow an estimate to be made of the radionuclide content of the candidate material, then it is possible to carry out screening dose calculations using the IAEA model. In its simplest form, their approach uses generic coefficients for dose per unit activity concentration calculated using reasonably conservative assumptions. However, the IAEA recommend that more specific dose coefficients be used whenever possible. This requires knowledge of

the dispersive characteristics of the coastal environment, local human habits, details of the dredging operation etc.

If candidate materials assessed by the Stepwise Evaluation Procedure are deemed to contain *de minimis* levels of specific activity, then they can be regarded as 'non-radioactive' for the purposes of the London Convention 1972 and may be disposed of at sea subject to the other provisions of the convention.

1.4 General Application of the IAEA advice

In many locations of the UK the radioactivity of dredged sediment has the potential to be enhanced above background levels, arising from the authorised discharge of liquid and gaseous wastes from nuclear establishments (Environment Agency et al., 2004). In these cases, assessments have been required on an *ad hoc* basis and for assurance that there is no significant risk (e.g. to the food chain) from the disposal at sea of dredged sediment. More recently, this has been achieved using the generic radiological assessment procedure developed by the International Atomic Energy Agency (IAEA, 2003) and produced primarily as a tool for countries without an advanced radiological protection infrastructure. The simplistic methodology is not designed to provide a realistic assessment; instead it is a screening tool that provides conservative dose estimates due to the underlying assumptions.

The International Atomic Energy Agency emphasise that the responsible authority should attempt to come to a decision at the earlier stages of the evaluation

process (Fig. 1), and that the generic radiological assessment should only be used when steps 1-5 have been fully considered.

1.5 England and Wales Approach to *de minimis* Assessments

With the publication of the full set of IAEA advice, Defra and CEFAS agreed that a more systematic assessment of the *de minimis* status of disposal operations around England and Wales was required. Application of the initial 5 steps in the Stepwise Evaluation Procedure to many of the candidate materials considered for disposal in the UK (e.g. sediments and fish waste) indicates that radiological assessments are likely be needed. This is because most are contaminated (albeit at very low levels) with radioactive discharges principally from Sellafield. The strategy adopted was to first carry out regional assessments for all relevant areas around England and Wales to identify where specific local assessments are required and ideally rule out some regions from requiring specific assessments. Specific assessments were expected to be required mainly, if not exclusively, in the Eastern Irish Sea.

It is intended to review the *de minimis* assessments periodically to confirm that the assumptions made in the original assessment remain valid. However, even where assessments have been carried out previously, re-assessment will be necessary if there are changes in the discharges of radioactive materials, if the volumes proposed for disposal change significantly or the disposal site location changes. In the latter case, changes in dumpsite characteristics would be the issue for consideration.

In the IAEA guidance, a set of conversion factors has been pessimistically derived which enable individual and collective doses to be calculated from concentrations of particular radionuclides in the candidate material. The calculations are performed for each radionuclide and then summed for comparison with the dose criteria. IAEA-TECDOC-1375 includes a description of the models used to derive the conversion factors and the default parameter values used in the calculations. For clarity, further details are provided in section 3.

In this project, sets of conversion factors will be derived that are more specific to proposed dumping operations in each of 9 regions around England and Wales (section 5). The operations represented will include dumping of maintenance dredged sediment from 9 regions around England and Wales (some close to nuclear establishments such as Sellafield, others more remote) and 1 to cover dumping of fish wastes. It is anticipated that these sets of conversion factors will then be applicable to most situations in these areas.

In the case of capital dredged material, 3 categories of material have to be considered in determining the requirement for specific assessments:

a) Where part of an arising consists of essentially maintenance dredged material i.e. recently deposited material at and immediately beneath the seabed, it should generally be treated as for maintenance dredged material in that port or region as appropriate.

b) Where an arising, or part of an arising, consists of geological material (i.e. material not previously exposed at the surface of the earth due to its depth

below the seabed), it is very unlikely to be contaminated and may not require a specific assessment i.e. it may be capable of being determined to be *de minimis* in steps 1 - 5 of the Stepwise Evaluation Procedure.

c) Where there is a risk of an arising, or part of an arising, consisting of historically contaminated sediments (in radioactivity terms), a specific assessment is likely to be required in each case. This assessment would be able to utilise the information already gathered for the regional or other local assessments, but there would be a need to include historic monitoring data and may also be a need for sampling and analyses.

1.6 Current Project

The objective of this project was to develop the region specific assessments for England and Wales mentioned in section 1.5 above, to enable early decisions to be reached in the future concerning the necessity for specific assessments for maintenance dredging applications for ports in those areas. As such this research is directly relevant to the work of Defra, as part of its targets to i) fulfil the responsibilities of the UK government towards the London Convention 1972 and ii) develop appropriate assessment and monitoring techniques to reduce marine pollution.

The work carried out here included a review of existing data concerning the sources and specific activity of radionuclides in dredged sediment, for individual regions, based on the previous Sea Fisheries Inspectorate (SFI, now the Marine Fisheries Agency or MFA) districts, around the UK. Information was also collated

to enable the calculation of appropriate dose coefficients. The available data were used to produce estimates of individual and collective dose to dredge operators and the public. In addition, an assessment was also carried for the disposal of fish waste in Cardigan Bay.

2. SOURCES OF RADIOACTIVITY, AND DREDGING ACTIVITY, IN COASTAL WATERS OF THE UK

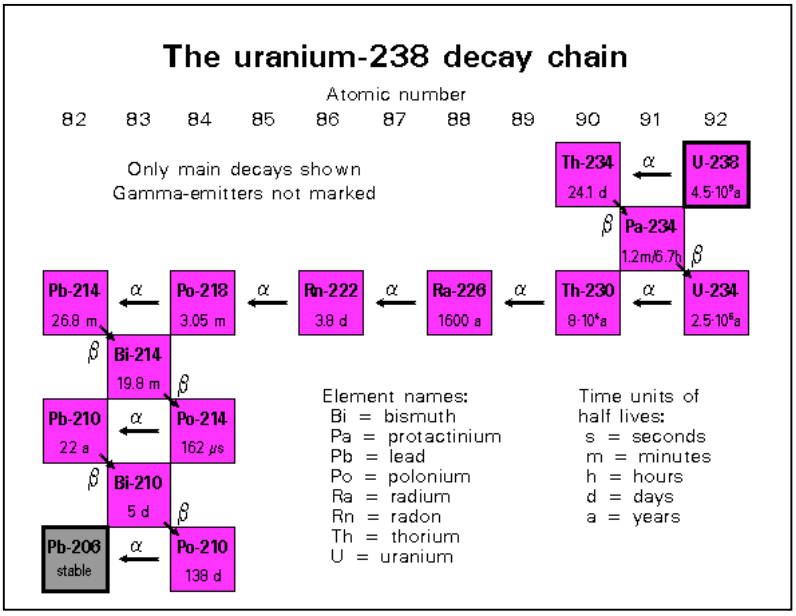
2.1 Radioactivity in the environment

Over sixty radionuclides can be found in the environment, and they can be placed in three general categories:

1. Primordial - present since the creation of the earth
2. Cosmogenic - formed as a result of cosmic ray interactions
3. Anthropogenic - enhanced or formed due to human actions

Primordial radionuclides have been present since the earth was created, and are therefore naturally occurring. They are typically long lived, with half-lives in the order of hundreds of millions of years. Uranium and thorium radionuclides are widely dispersed and common components of the earth's crust. Natural uranium, by mass, is 99.3 % ^{238}U and ~0.7 % ^{235}U. Thorium is, by mass, essentially 100 % ^{232}Th. The radioactive decay of ^{238}U, ^{235}U and ^{232}Th results in the formation of a large number of daughter products with variable half-lives and radioactive emissions (see Fig. 2 for a schematic illustration of the ^{238}U decay series). These three radionuclides, and their daughter products, are present in both the water column and seabed sediments of all UK coastal waters.

Figure 2 - Schematic diagram of the ^{238}U decay series



Cosmogenic radionuclides such as ^{3}H and ^{14}C are continuously produced in the upper atmosphere as a result of cosmic ray induced spallation and particle interactions. They are, therefore, also of natural origin. The majority have shorter half-lives than the primordial nuclides and are transported into coastal waters via the hydrologic cycle.

Some radionuclides arise from human activities such as industrial, medical or military uses of artificial radionuclides. In addition, sources of natural radionuclides (e.g. uranium) are concentrated by mining and other industrial activities. Humans have used radioactivity for one hundred years, and through its use, added to the natural inventories. This is true of UK coastal waters, most notably the Irish Sea, arising from nuclear fuel processing and power generation.

2.2 Background levels of natural series radionuclides

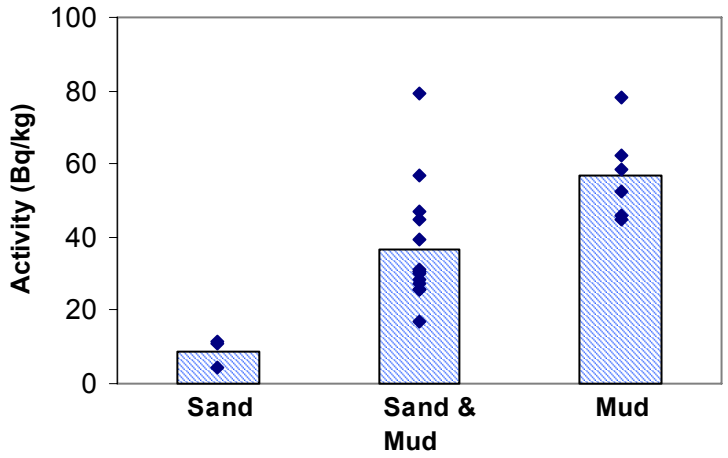
As mentioned previously, uranium and thorium are common components of the earth's crust. The distribution is, however, heterogeneous and concentrations of uranium and thorium in marine sands and clays are typically in the range 1 to 4 and 1 to 30 ppm, respectively (Ivanovich and Harmon, 1982). Uranium is found scattered in the faults of old igneous rocks. Thorium occurs in monazite and in uranothorite (a mixed Th,U silicate). Levels of uranium and thorium in coastal UK sediments are, therefore, variable, dependent upon the local geology. Another source of variation is grain-size as the activity tends to be greater in finer grained material (Emerson and Young, 1995; Noureddine et al., 1998).

Published data concerning activities of natural series radionuclides in marine sediments, and applicable to the present project, appear sparse. The majority of data refer to measurements made in the course of geochemical and sedimentation studies in open waters. Background levels of ^{238}U and ^{232}Th in Irish Sea sediments have been reported to be in the range 1-20 and 5-30 Bq/kg, respectively (McCartney et al., 1990). Unfortunately data for these nuclides are not reported for most sediment samples analysed as part of routine monitoring programmes to assess radioactivity in the environment (Environment Agency et al., 2004). Nevertheless, information concerning their activity is required for the dose assessments carried out for the present study. Unpublished data, derived from the assay of gamma emitting radionuclides in a limited number of sediment samples by CEFAS for the Food Standards Agency (FSA) were, therefore, evaluated to estimate likely ranges in sand and mud. The sampling sites were distant from known anthropogenic inputs of natural radionuclides and were

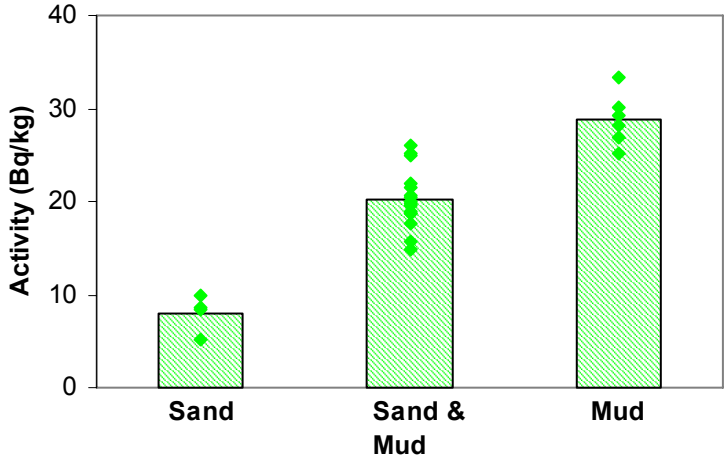
distributed around the coastline of England and Wales. The activities of ^{238}U, ^{226}Ra and ^{232}Th in these samples were inferred from values for their gamma emitting daughter products ^{234}Th, ^{214}Pb and ^{228}Ac, respectively. Although the errors associated with individual measurements are significantly greater than results derived from assay of the parent radionuclides by conventional α-spectrometry, the screening values are valuable and fit for purpose for the present project (Fig. 3).

Figure 3 - Indicative activities of selected natural series radionuclides in marine sediments around the coastline of England and Wales, at sites distant from known anthropogenic inputs. Dots indicate individual measurements and bars the average values.

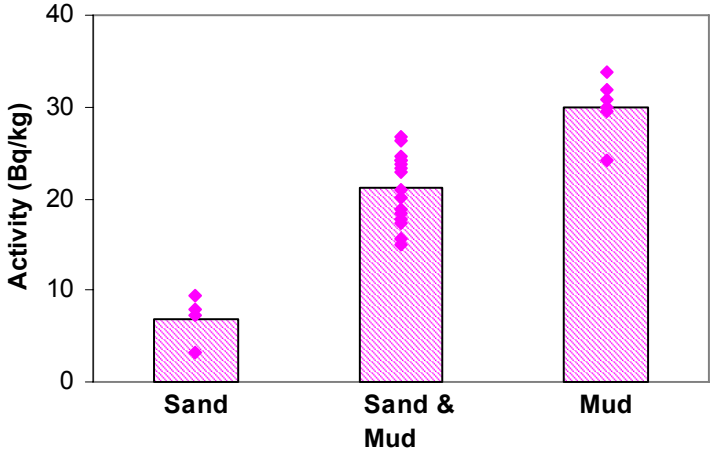
a) ^{238}U



b) ^{226}Ra



c) ^{232}Th



The scatter in the data in Figs. 3a-3c demonstrates that it is impossible to assign unique background activities for naturally occurring radionuclides due to the aforementioned sources of variation. In general terms, lower levels were observed in sandy material reflecting the lesser surface area available (per unit mass) for sorption. The average activity in fine-grained mud was greater than that in sand by ~4-6 fold. It seems reasonable to assume that, for local disposal, material removed in routine maintenance dredging operations will have similar levels of activity to seabed sediments at the disposal site. Therefore, unless anthropogenically enhanced levels were known to be present in a particular port (e.g. such as Whitehaven), the impact upon public exposure was assumed to be zero in the regional assessments (section 5). In the absence of information to the contrary, dredge operators were assumed to be exposed to levels typical of muddy material (i.e. ~60 Bq/kg ^{238}U, ~30 Bq/kg ^{226}Ra, and ~30 Bq/kg ^{232}Th) to indicate maximum dose. Predicted doses to crew (section 5), arising from 'background levels' of uranium and thorium radionuclides, were in the range ~3-5 μSv/a and therefore constituted a significant proportion of the *de minimis* criteria.

2.3 Radioactive discharges

Authorised discharges of radioactive wastes as liquid or gases are released from all the main nuclear sites in the UK. Their locations, along with the major UK dredge material disposal sites, the quantities of material disposed in 2003 and major surface currents in winter, are shown in Fig. 4.