GUIDELINES FOR THE ASSESSMENT OF DREDGE MATERIAL FOR DISPOSAL IN IRISH WATERS

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Front Cover: Dredging by Eco-bucket, Castletownbere Harbour Co. Cork (Copyright Marine Institute)

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SUMMARY

Prior to the present guidelines the assessment, by the Marine Institute on behalf of the Department of Communication, Marine and Natural Resources, of the suitability of dredged materials for disposal at sea had employed provisional action levels as an aid to evaluation. These provisional action levels were based entirely on sediment chemistry. The responsible agencies have decided that these levels now need to be updated and formalised.

The approach proposed in this document aims to provide an improved, and more integrated, assessment of the ecological risks associated with individual sediment dredging and disposal activities. It offers flexibility to deal with issues on a case-by-case basis and improves transparency of the decision-making process.

The list of parameters to be assessed has been revised and methods for setting numerical guidance values in other countries have been reviewed. Ideally, guidance levels should comprise chemical and ecotoxicological data specifically relating to Irish sediments.

In the absence of a comprehensive dataset for Irish sediments, proposed threshold guidance levels have been based on ecotoxicological data from other sources. Wherever possible, lower threshold guidance values have been based on existing Irish background levels of contaminants. Where background data do not exist for a particular parameter, ecotoxicologically-derived values, corresponding to expected no-effect levels, have been taken from reputable sources.

Similarly, upper threshold guidance levels (i.e. levels at which effects may be expected) have been based on ecotoxicological data from reputable sources.

The assessment strategy has been designed so that decisions concerning the acceptability of sediments for sea disposal will take into account a range of intrinsic and environmental factors i.e. the strategy adopts a Weight of Evidence approach. The guidance will be reviewed and revised as necessary, as more information becomes available.

Sampling and storage methodology is presented as well as quality assurance and reporting requirements. Guidance on analytical procedures and approval of analytical laboratories is included.

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1.0 Introduction

Sedimentation in the marine environment is a natural phenomenon, occurring by rivers eroding material in upstream areas and settling suspended matter when the current becomes slower, runoff by lowland rivers or by currents, coming from the sea, transporting and settling material in protected areas such as ports.

Contamination of these sediments occurs when natural or human activity results in the introduction of contaminants that can cause undesirable impacts on the environment. Many of these introductions take the form of waste discharges that are mixed with the sediments when they settle.

The settlement of sediments in approach channels to ports and within port areas themselves results in the necessity to remove this material by dredging in order to keep navigation channels clear (maintenance dredging). Additionally dredging may be necessary during the construction of coastal engineering projects, like harbours, marinas and pipelines (capital dredging). The maintenance of navigation channels is important to ensure safe access to ports and harbours and is particularly important for an island nation like Ireland where more than 98% of goods imported and exported pass through our ports.

Depending on the quantity and nature of the dredged material involved several options are available for its subsequent handling and management. These options include;

- Beneficial reuse e.g. beach nourishment, land reclamation, construction
- Disposal on land in licensed land fill sites
- Disposal at sea

The Department of Communication, Marine and Natural Resources (DCMNR) has issued an average of 16 permits per year for dumping at sea since 1996. These cover a quantity of some 2 million tons of material per year. Data available from OSPAR show that in 1996 the amount of dredge spoil disposed of at sea in Ireland represented approximately 1.2% of the total disposed of in the OSPAR area as a whole. Most of these permits have been granted for the dumping of dredged spoil from ports and harbours.

Approvals for dumping at sea are based on the advice of the Marine Licence Vetting Committee (MLVC). This is an inter agency group, which manages the application and vetting process for dumping at sea. Applications typically have to be accompanied by reports of site surveys, benthic surveys, dispersion models, chemical analysis of the material, grain size and other surveys that may be required.

1.1 Purpose of the Sediment Quality Guidelines

This section of the document explains the background to the guidelines and the nature of the concerns regarding sediment contamination. It also discusses the limitations of the previously employed procedure for assessing the environmental hazards associated with dredged material disposal at sea. It then outlines a revised and improved assessment strategy and some of the key considerations in the development of numerical sediment quality guidelines.

The cruise liner Nordnorge at Custom House Quay, Cork (Reproduced with kind permission of Port of Cork)

To date, no coherent strategy has been developed in Ireland for dealing with the disposal of dredged material. There is a need for clear guidelines that provide consistent standards and criteria for assessing applications for sea disposal and reduce confusion amongst applicants concerning the investigations and assessments required.

By improving the information upon which risk assessment and impact analysis is based, such guidelines will facilitate decision-making by the responsible regulatory bodies, including the Department of Communications, Marine and Natural Resources (DCMNR) and the Marine Institute (MI).

In order to address these issues, the DCMNR requested MI to establish an expert group with the following terms of reference:

- Review existing national and international legislation governing the disposal of dredge spoil, including the OSPAR and London Conventions.
- Describe the current national infrastructure for handling and disposal of contaminated dredge spoil and identify future requirements.
- Identify areas in Ireland with highly contaminated sediments, with particular focus on key commercial ports and fishing harbours.
- Review the list of chemical contaminants that should be analysed in dredge spoil.
- Prepare guidelines on sampling and analysis of dredge spoil, including toxicity testing.
- Review the existing Irish criteria to determine the suitability of dredge spoil for sea disposal.
- Review international best practice for handling and disposal of contaminated dredge spoil.
- Prepare guidelines for DCMNR and the relevant authorities on the handling and disposal of contaminated dredge spoil in Ireland.

The purpose of these Guidelines is to establish a comprehensive national framework for assessing the quality of dredged material and, in particular, for assessing likely impacts arising from the dumping at sea of contaminated sediments.

Handling and disposal of dredged material will be dealt with in a separate volume.

1.2 The nature of the problem

Marine sediments are not, in themselves, polluting substances. Rather, they can be a sink for contaminants that end up in our harbours and ports mainly from anthropogenic sources such as sewage discharges, marine traffic, industrial wastewater and historically poor environmental management.

Contaminants in sediments can act as a source of long-term environmental pollution. Certain substances can be bioaccumulated in benthic organisms resulting in biomagnification at higher levels in the food chain. Some widespread pollutants e.g. polychlorinated biphenyls (PCBs) are no longer in use but due to their persistence they can still be detected in marine sediments.

1.3 Sources of contamination

The substances that are considered of most concern for the marine environment are those with combined properties of persistence, *t*oxicity and liability to bioaccumulate (PTB). Typically, the most important contaminants associated with dredged material include organotin compounds, heavy metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and oils (OSPAR, 2004).

Organotin compounds generally enter the marine environment from biocide products applied to vessels to prevent organism-fouling[1]. Tributyl tin (TBT) is the main organotin compound of concern and is by far the most toxic to marine life. TBT is responsible for the disruption of the endocrine system of marine shellfish. It also impairs the immune system of shellfish causing shell malformations after exposure to even extremely low concentrations in seawater. TBT degrades slowly (especially in anoxic sediments) to form the breakdown products dibutyl tin (DBT) and monobutyl tin (MBT). These compounds are less toxic than the parent product but may still be hazardous to marine life.

Heavy metals occur naturally in sediments and waters as a result of rock weathering. However, concentrations above natural background levels can result from anthropogenic inputs. Metals of concern include mercury, lead, cadmium, copper, zinc, arsenic, nickel and chromium. While some of these are essential elements at low doses (e.g. copper, zinc), all are toxic at high concentrations. The effects of heavy metals include damage to the liver (cadmium), central nervous system (mercury) and cell membrane (copper).

High molecular weight halogenated hydrocarbons such as organochlorine pesticides and PCBs are part of a group of contaminants known as persistent organic pollutants (POPs). Although the use of many of these compounds has been prohibited for many years, their resistance to degradation means that they can persist for long periods of time in marine sediments. PCBs were used in electrical equipment, insulating materials and hydraulic fluids, as well as paints, plastics & adhesives. Some pesticides (e.g. DDT and its derivatives) are almost ubiquitous in the marine environment due to atmospheric deposition.

Oil and its combustion products contain a variety of polycyclic aromatic hydrocarbons (PAHs). Some PAH compounds are known to be carcinogens and mutagens. There is evidence to suggest that PAHs may cause adverse, but sub-lethal, effects in organisms at sites with chronic, low-level contamination in the marine environment. Such effects may induce further changes such as in enzyme activity, reproductive failure and reduced growth potential. Inputs of PAHs to marine waters are chiefly from atmospheric deposition and the dumping of dredged material from ports and harbours (OSPAR, 2001).

Although other contaminants, such as radionuclides, are seldom present in Irish sediments at levels of concern, a wide range of substances may require testing under OSPAR guidelines.

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[1] In 1987, the aggressive biocide and antifoulant tributyl tin (TBT) was prohibited in Ireland for use on boats less than 25 metres in length, but yet continues to cause problems in some Irish ports. In 1999, the International Maritime Organisation (IMO) adopted an Assembly resolution calling for a global prohibition on the application of organotin compounds by 1 January 2003, and a complete prohibition by 1 January 2008. In response to this, a EU regulation brought into force in 2003 gave effect to the terms of the new 2001 IMO convention in respect of EU registered ships as well as ships travelling in EU waters.

1.4 Current Irish approach

Dumping of dredged materials at sea is regulated internationally by the London Convention 1972 (including the 1996 Protocol), and the OSPAR Convention for the Protection of the North East Atlantic (1992). Although impacts are associated with both dredging and disposal, the act of dredging itself is not covered by the Conventions. OSPAR has produced Guidelines for the Management of Dredged Material (OSPAR, 2004).

National legislation for sea disposal of dredged sediments is implemented through the Dumping at Sea Act, 1996 (amended 2004). The criteria governing the grant of permit for dumping at sea are set out in the First Schedule of the Dumping at Sea Act, 1996. Typically, information is required on the physical and chemical characteristics of the sediments and, if deemed necessary, their potential biological impacts.

On applying for a Dumping at Sea permit, the port authority (or company responsible) should submit to the Department of Communications, Marine and Natural Resources the following information:

- Location of area to be dredged (with co-ordinates & map)
- Quantity of material to be dredged
- Visual granulometry (% gravel, sand, silt and mud) from borehole analysis
- Details of previous sediment analysis (copy of most recent report)
- Alternatives to sea disposal
- Location of proposed dumpsite and whether it has been used previously
- Copies of any survey results associated with the dumpsite, e.g. archaeology.

The trailing suction hopper Amazone in Cork Harbour. (Reproduced with kind permission from Port of Cork)

An initial assessment to determine the suitability of the sediment for sea disposal is carried out by MI scientists on the basis of the above information. If the volume of sediment is low and the material is thought to be unaffected by local, or other sources of contamination, or is composed entirely of coarse material (sand and gravel), then further testing might not be required. On the other hand, sediments composed of predominantly fine-grained matter typically require chemical analysis, because many contaminants have strong affinity to the clay fraction.

Assessment of the area and the material to be dredged takes into account proximity to point sources of pollution, e.g. oil refineries (hydrocarbon pollution), boatyards and piers (TBT contamination), urban runoff (metals, PCBs), and available information of historical activities that may have resulted in pollution. Previous chemical analysis of sediment samples from the surrounding area is also considered. If satisfactory analysis was carried out in the previous five years, indicating no potential contamination problems, then further analysis may not be necessary.

The location and characteristics of the proposed dumpsite are also considered. If a new dumpsite is proposed, then a full hydrodynamic survey, a benthic survey and an archaeological study are required. If an existing dumpsite is to be used, recent reports on dispersion and sensitivity of the benthos are considered.

Based on the aforementioned information, together with knowledge of historic data, activity and point sources of pollution, the

Marine Institute advises on a sampling and analysis plan for the area (see Section 2). Within this sampling plan, analytical criteria (such as limits of detection and quality assurance requirements) and information to be included in the analytical report are also specified. A number of samples are also required for radiological testing. Advice on sample collection and storage is provided by the Radiological Protection Institute of Ireland (RPII).

To date, the assessment of the suitability of dredged material for dumping at sea has been considered on a case-by-case basis, using *Provisional Irish Action Levels* as a guide, (see Annex 2) and has been based almost entirely on sediment chemistry[2]. The range of parameters to be tested was selected as the most pertinent at that time and designed to give a good indication of the overall levels of contamination in the sediment.

1.5 Necessity for a new system

The previous system, while fit for the purpose at the time, is now outdated. Several chemical and ecotoxicological parameters included in the current guidelines, were not previously used, and there was a lack of criteria specific to Irish sediments.

The *Provisional Irish Dredged Spoil Action Levels* were formulated for metals, TBT and PCBs only and referred solely to the chemistry of the sediments. Chemical concentrations of contaminants in sediments do not necessarily indicate the degree of toxicity (GIPME, 2000) Combined effects and bioavailability are key factors in determining toxicity. Furthermore, chemical testing focuses on a particular suite of priority determinants. In the event of chemical analysis identifying a contamination problem, no agreed strategy has been in place to enable a more ecologically relevant assessment and, in particular, a toxicological assessment of sediments.

Given the uncertainties associated with reliance on chemical testing to predict ecological risk, a more holistic and robust approach is required. The new approach aims to provide an improved and integrated assessment of ecological risk associated with individual dredged material disposal operations. It will take account of bioaccumulation and toxicity potential. It offers flexibility to deal with dredged material management issues on a case-by-case basis and improves transparency of the decision-making process.

In line with the OSPAR guidelines (OSPAR, 2004), two *Action Levels* (See Section 1.5) are proposed covering an expanded list of contaminants. It is also proposed to use a *Weight of Evidence* (WoE) approach to assess the suitability of sediments for sea disposal (Burton *et al*., 2002, Ahlf *et al*., 2002, Burton 2002). This involves examining many lines of evidence as opposed to assessing solely sediment chemistry.

Bioavailability, the fraction of chemical present that is available for uptake by aquatic organisms, is of prime importance in assessing the potential for toxicity of a sediment. This aspect of contamination has not previously been adequately addressed in assessing the suitability of sediments for sea disposal.

Sediment analysis gives an overall quantitative view of the degree of contamination. However, in many cases, the total amount of contaminant present may not be available for uptake by organisms due to adsorption to organic particles or binding within clay lattices. Bioavailability generally refers to how much of a contaminant is “available” to have an adverse effect on biota (Naval Facilities Engineering Service Centre (NFESC), 2000).

In addition, available volatile sulphides (AVS) bind to divalent metals in anoxic sediments causing them to precipitate out as insoluble sulphides. This reduces the partitioning of the metals to the pore water, thus reducing their bioavailability to organisms in that medium. This binding can be reduced when the sediments are disturbed and oxic conditions introduced.

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[2] Occasionally, whole sediment bioassays / Microtox porewater tests have been requested in support of a Dumping at Sea application. Much work has been done outside of the regulatory process in relation to toxicity testing in Ireland.

Measurement of total concentrations of contaminants gives an overall quantitative picture but does not necessarily reflect the chemical form/species of the contaminant. Most metals can exist in a variety of states and/or species (chemical form) and this can have a significant effect on toxicity.

Toxicity, described as *"the degree to which a chemical substance elicits a deleterious or adverse effect upon the biological system of an organism exposed to the substance over a designated time period" (*USEPA, 1996), is another property that, to date, has not been dealt with systematically in the Irish assessment process.

The toxicity of a substance is manifested in several ways. Acute toxicity results in a rapid reaction (often death) following a short period of exposure relative to the expected lifetime of the organism. Chronic toxicity results from a prolonged period of exposure to concentrations that are sometimes well below those causing acute toxicity. Chronic toxicity may be manifested by a wide variety of sub-lethal responses e.g. impaired reproduction or enzyme activity, physiological effects such as scope for growth and behavioural changes. Both modes of toxicity should be investigated in order to assess potential toxic effects within a particular sediment sample.

Toxicity is typically expressed as the Effective Concentration for half of the exposed population in a specified time period (e.g. 24-hr EC_{50}). Where the response is death, this becomes the Lethal Concentration i.e. 24-hr LC_{50}.

1.6 Development of sediment quality guidelines (SQGs)

Sediment Quality Guidelines (SQGs) provide a practical set of tools for use in assessing contaminant levels in sediments proposed for sea disposal. The most widely employed approach within the OSPAR region is the use of two action levels (upper and lower) as outlined in the relevant guidance document (OSPAR, 2004). The results of the assessment either permit the sediment to be disposed at sea or will bring into play further testing protocols or alternative disposal methods.

The lower level (Level 1) defines a concentration (i.e. guidance value) of a contaminant in sediment below which biological effects would not be anticipated.
The upper level (Level 2) defines a contaminant concentration above which biological effects are anticipated to occur. It can be assumed that, for any given sediment, the more parameters exceeding this level, and the greater the margin between the guidance value and the measured value, the greater the likelihood of biological effects.

Sediments with contaminant concentrations exceeding the relevant upper level guidance values would be classed as heavily contaminated; they may cause biological effects and will require further assessment.

1.6.1 Derivation of chemical guidance values

Numerical guidance values can be set on many bases, for example:

- by reference to background sediment chemistry,
- toxicological testing including sediment bioassays,
- field toxicity observations/simulations,
- factorisation of reference values.

The approach can be either empirical or theoretical. Empirical values can be derived from existing sediment chemistry and, where available, ecotoxicological measurements. Theoretical values can be based on the predicted bioavailability of a contaminant taking into account factors such as reduced bioavailability due to AVS, OC etc. (Glossary: Annex 1)

The 2002 SETAC Pellston Workshop reviewed different SQG approaches and the scientific basis for them. It concluded that "though the scientific underpinnings of the different SQG approaches vary widely, none of the approaches appear to be intrinsically flawed. All approaches reviewed are grounded in concepts that, viewed in isolation, are sound." (Wenning & Ingersol, 2002).

In 2003, the International Council for the Exploration of the Seas (ICES) Working Group on Marine Sediments in relation to pollution (ICES WGMS, 2003) reviewed various methods used in developing numerical SQGs. While all methods have advantages and disadvantages, the Working Group concluded that some are too simplistic, ignoring variations in bioavailability or assuming consistent routes of exposure.

The following were considered as possible methods for setting numerical SQG values:

(a) Sediment/water equilibrium partitioning

Sediment quality guidance values can be derived from field toxicity simulations, that is to say, values derived from partitioning of contaminants between sediment and water (Kow). This method gives the concentrations expected in the water column relative to concentrations present in the sediment. These can then be compared with existing water quality criteria. The guidance value can be selected so as to keep the contaminant concentration in the water phase below that likely to cause toxicity to organisms inhabiting the area of the dumpsite.

This method takes into account only toxicity caused by ingestion or absorption of contaminants in interstitial (pore) water and not toxicity to deposit feeders through ingestion of contaminated sediment particles.

(b) Food safety

This approach is similar to field toxicity simulations whereby partitioning is taken into account. In this instance, however, the amount of the contaminant accumulating in fish flesh is predicted to ensure human health levels will be respected (e.g. those set by the EC, 2001).[3] These levels are set for mercury, cadmium, lead, sum of dioxins and benzo(a)pyrene.

(c) Background levels of contaminants in Irish sediments

Background concentrations of metals and organic compounds in sediments are an essential consideration in any sediment assessment process. The term *background* applies to substances that occur ubiquitously in marine sediments either as a result of natural geological properties or long-term, widespread and low-level inputs from land-based activities via rivers and the atmosphere.

For substances that do not occur naturally, such as many organochlorine compounds, the background value is theoretically zero. However, their ubiquitous occurrence means that there are low and measurable concentrations throughout the region that can be considered background values. This is the approach proposed for deriving the lower guidance values for Irish sediments.

Although the background level of a contaminant may vary spatially, for consistency one guidance figure is used for the entire coastline but the assessment procedure takes into account natural spatial variations.

(d) Ecotoxicological data

Information from the United States, comprising chemical and biological effects data for more than 1000 sediment samples, has been widely used as a basis for setting threshold effect values.

Several sediment quality criteria are used, in particular the:

- Effects Range Low / Effects Range Median (ERL/ERM); (Long *et al*., 1998)
- Threshold Effects Level / Probable Effects Level (TEL / PEL); (MacDonald, *et al*., 1996), and
- Apparent Effects Level, low and high (AET-L and AET-H). (PTI Environmental Services, 1991)

(Annex 6 gives a brief explanation of the above terms.)

These approaches make use of data from many studies. Of the three methods listed above, the ICES Working Group on Marine Sediments in Relation to Pollution (WGMS 02) favoured the ERL/ERM approach over the others as it is sufficiently conservative, has received most validation and is simpler to operate. This method was used for the derivation of upper guidance level values in Ireland.

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[3] Commission Regulation (EC) No. 466/2001 amended by Commission Regulations (EC) No. 2375/2001, 221/2002, 78/2005, 208/2005

Although it is considered that these ecotoxicological guidelines are non-transferable and should be used only in the correct geographical context, in the absence of local data many countries have made use of data from overseas. For example, Level 2 values (equivalent to the upper guidance level) in the proposed UK guidelines were guided by ecotoxicologically-derived values (ERL/ERM).

The addition of ecotoxicological tests to the suite of sediment analyses will generate sufficient data on Irish sediments to validate the suitability of the selected interim values.

(e) Other approaches

One method commonly used to derive upper level guidance values is to multiply lower guidance level values by a set factor in order to estimate a value above which biological effects might be expected. For example, Germany applies a factor of 5 to the selected *background* (Level 1) values to set upper guidance level values for metals (results based on <20μm fraction) and a factor of 3 for organic contaminants (results based on <2mm fraction).

In transboundary water bodies, it is appropriate to consider guidance values established by the neighbouring jurisdiction, providing those values have a sound scientific basis and are applicable to local geology, chemistry and ecology. Ireland shares waterbodies with Northern Ireland in Carlingford Lough and Lough Foyle.

1.7 New guidance values for Irish sediments

Key considerations in the choice of guidance values for Irish sediments are the range of determinants to be included and the means by which individual values should be selected. These issues are discussed below.

Examples of guidance values set by other countries, which have been taken into account in developing Irish values, are given in Annex 6.

1.7.1 Parameters to be included

Certain substances are subject to mandatory assessment under OSPAR[4] guidelines (OSPAR 2004). In all cases where analysis is required, heavy metals will be included. Metals exhibiting toxic effects at elevated concentrations include:

- arsenic
- copper
- cadmium
- chromium
- lead
- mercury
- nickel
- zinc.

The metals lithium, aluminium and manganese are included because their concentrations reflect the natural geochemistry of the area and can help to explain variations in the levels of other metals i.e. they can be used as *normalisers*.

Analytical data for TBT and DBT will be requested for all Dumping at Sea permit applications. TBT is arguably the most toxic substance introduced by man to the marine environment (Evans *et al*., 1995). Although banned since 1989 on boats less than 25m in length, several Irish fishery ports are still heavily contaminated with TBT.

PCB analysis will continue to be requested. Although these substances are rarely detected above the provisional upper action level values in Irish sediments, there have been incidents of gross contamination in the recent past, due to inputs from point sources. The seven indicator PCBs selected by ICES will be requested[5]. However, should initial testing of indicator PCBs show elevated levels, testing for a broader suite of PCBs may be required.

Examination of data from sediment analyses carried out on samples from Irish ports and harbours has shown that the majority of organochlorine pesticides (OCPs) examined have not been detected over the last ten years and more. Table 1.1 shows the incidence of occurrence of these pesticides.

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[4] OSPAR guidelines for management of dredged material. 2004

[5] CB congeners 28, 52, 101, 118, 138, 153, and 180.

Table 1.1 Incidence of detection of organochlorine pesticides in Irish sediments[5].

Parameter	No. times OCP detected/ no. of times analysed	% incidence of detection
Aldrin	0/128	0.0
α-HCH	0/128	0.0
β-HCH	0/128	0.0
χ-HCH	15/128	11.7
Dieldrin	4/128	3.1
Heptachlor	0/128	0.0
Heptachlor epoxide	0/128	0.0
DDT (op)	0/128	0.0
DDE (pp')	15/128	11.7
DDT (pp')	0/128	0.0
TDE (pp')	0/128	0.0
Endrin	0/128	0.0
Endosulfan Alpha	0/128	0.0
Endosulfan Beta	0/128	0.0
HCB	13/128	10.2

Other marine monitoring programmes in Ireland do not indicate problems associated with organochlorine pesticides (MI, in prep). This is not unexpected, as most of the substances have long been banned for use in Ireland and Europe - some since the early 1980s. Where an OCP is detected at low levels, the origin may not be local or recent and the residues most likely stem from atmospheric inputs.

As a result of these findings, it is proposed to exclude OCPs from routine sediment analyses with the exception of γ – HCH (Lindane) and HCB, which may be required in some instances. Both of these substances are listed as priority hazardous substances under Annex 10 of the Water Framework Directive 60/2000/EC[6] (EC/WFD, 2001). Both have been detected in sediments in Irish waters.

Determination of polycyclic aromatic hydrocarbons (PAH) will be requested for sediments from ports where urban runoff is expected. It will also be required if a known source exists or if elevated levels of Total Petroleum Hydrocarbons (TPH) are detected. Provisionally, the US EPA list of 16 PAHs[7] will be requested and assessed. In the event of a known point source, or the reporting of high concentrations, other compounds may be added to the list of requirements, such as alkylated PAH which would be associated with petrogenic rather than pyrogenic (combustion) sources.

1.7.2 Unanticipated contaminants

The list of determinants requiring special attention is based on current knowledge. It is not possible to anticipate all chemicals that may be problematic in the future, for example due to their inherent toxicity and tendency to accumulate in the environment.

Whereas these guidelines outline basic requirements for assessing the type and degree of sediment contamination, not all sediments will require analysis for all substances listed. Depending on the circumstances, MI on behalf of DCMNR may determine, based on expert judgement, that a reduced set of analyses is appropriate. On the other hand in some instances broader chemical assessments beyond the core suite of determinands may be necessary, for instance to identify the reason for a measured toxicity response.

In cases where it is deemed necessary to search for a broader range of hazardous substances, qualitative analytical screening techniques, for example scanning gas chromatography - mass spectrometry (GC-MS) may be employed.

1.8 Setting guidance levels

The parameters and proposed lower and upper guidance level values to be considered in assessing the suitability of dredged material for disposal at sea are listed in Table 1.2. These values are based on a standardised sediment with organic carbon content of 3%,

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[6] Commission decision 2455, 2001

[7] Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(ah)anthracene, Benzo(ghi)perylene, Indeno(123-cd)pyrene

aluminium content of 6.5% and lithium content of 0.2%.

Table 1.2 Parameters and proposed guidance values for sediment quality guidelines.

Parameters	Units (dry wt[a])	Lower level	Upper level[b]
Arsenic	mg kg^{-1}	9[c]	70*
Cadmium	mg kg^{-1}	0.7	4.2
Chromium	mg kg^{-1}	120	370
Copper	mg kg^{-1}	40	110[d]
Lead	mg kg^{-1}	60	218
Mercury	mg kg^{-1}	0.2	0.7
Nickel	mg kg^{-1}	21	60
Zinc	mg kg^{-1}	160	410
Σ TBT & DBT	mg kg^{-1}	0.1	0.5
γ – HCH (Lindane)	µg kg^{-1}	0.3	1
HCB	µg kg^{-1}	0.3	1
PCB (individual congeners of ICES 7)	µg kg^{-1}	1	180
PCB (Σ ICES 7)	µg kg^{-1}	7	1260
PAH (Σ 16)	µg kg^{-1}	4000	
Total extractable hydrocarbons	g kg^{-1}	1.0	

[a] total sediment <2mm

[b] ERM (rounded up)

[c] ERL (rounded up) – No background Irish data available

[d] PEL as ERM considered high

* In some locations natural levels of arsenic will exceed this value and in such instances this guidance value will not be appropriate

1.8.1 Level 1 (lower level)

Metals

Most upper level guidance values have been derived from samples collected at reference sites around the Irish coasts deemed to be remote from point sources. Where elevated values were found with no explanation, these values were removed from the dataset. When the 95%ile of the remaining background data were considered, they were found to compare well with SQGs used elsewhere (Annex 6). These figures have been taken as lower threshold values for metals. In the case of arsenic and nickel, insufficient Irish background data were available therefore the ERL was selected as an interim measure.

These lower level guidance values for metals represent high background concentrations. It is estimated that 5% of data from uncontaminated samples would exceed this value.

Organics

For organochlorine pesticides and PCBs, 95%iles of background data were used to set the lower guidance level values[8]. No natural background figures exist for these substances but they are widespread in the environment. The values have not been normalised but future assessments will take into account any results showing elevated levels of organic carbon.

Lower level guidance values for PAHs have been set using the 95%iles of Marine Institute data. These data are quite limited in number. As a consequence, these values will be reviewed as more reliable data become available. Although no data are available from locations remote from point sources, levels of PAHs in Irish sediments are considerably lower than the equivalent ERL/TEL values.

Although information on organic carbon content was available for some of the samples analysed for PAHs, it was decided to use non-normalized guidance values to maintain consistency with values for other organic substances[9].

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[8] TOC levels not available for these sediments but it is assumed that TOC corresponds to typical background concentrations.

[9] Median concentration of OC found to be 2.3%. This will be referred to in future assessments where OC values are significantly different.

Organotins

Lower level guidance values for organotins are problematic to set in view of the nature and behaviour of the chemicals. TBT contamination tends to be localised in particular areas, although sometimes these areas are quite large. TBT may eventually become granulated within the sediment due to local hydrodynamics and its relatively long half-life of about 2.5 years in oxic marine sediments (De Mora, 1995, cited in J. Lintelmann *et al,* 2003). Nevertheless, TBT is not ubiquitous in the marine environment and natural background levels should be zero.

TBT toxicity is frequently observed in shellfish, often at very low concentrations. The previous provisional guidance level will continue to be used in the absence of information advising otherwise, however it will now represent the sum of TBT, DBT and MBT (where determined) and is therefore more precautionary and in line with other jurisdictions.

1.8.2 Level 2 (upper level)

It is acknowledged that the ideal method to derive ecotoxicologically based guidance values for Irish sediments is to use matching chemical and ecotoxicological data derived from tests on Irish sediment samples. In the absence of an Irish equivalent dataset, however, upper level guidance values are based primarily on available ecotoxicological datasets (ERM / PEL / AET – H). The natural range of metals in Irish sediments was also taken into account. As far as possible the values set for Irish sediments should be compatible with those used elsewhere.

Annex 3 lists datasets for lower and upper level guidance values from the most commonly used biological effects guidelines. Although these datasets originate in the US, they are referred to and have been used to derive guidance values in various countries such as Australia, UK and China (Hong Kong). The values taken from these datasets will be revisited at a future time and revised if necessary, to take into account relevant Irish data generated through implementation of these guidelines.

Although these guidance values cannot be applied emphatically, they do reflect potential for toxicity. Thus they can help in identifying and prioritising areas containing sediments of particular concern.

Where appropriate, studies of toxicity & bioaccumulation, as well as surveys of benthic communities, may be used to verify findings. from the assessment of analytical data.

1.9 Revised assessment strategy

1.9.1 A weight of evidence approach

The assessment strategy outlined in this document provides a framework with which to gauge the potential impact and ecological risk associated with the disposal of sediments at sea. Given the uncertainties in assessing potential ecological risk, over-reliance on individual indicators such as sediment chemistry should be avoided. Therefore the strategy applies a '*weight-of-evidence*' (WoE) approach to the decision making process (Ahlf *et al*. 2002, Burton 2002). In this approach, decision-making is based on integrated multiple '*Lines-of-Evidence*'. For a dumping at sea application such lines of evidence may encompass, *inter alia*:

1. Sediment Quality

- Sediment quantity
- Physico-chemical characteristics
- Contaminant concentrations, taking into account factors e.g. normalisation.
- Contaminant load intended for disposal
- Sediment toxicity (measured)
- *In situ* biology e.g. epi- and infauna
- Other indicators, such as contaminant levels in organisms, or biomarkers.

2. Dredging / Disposal operation

- Impact of dredging operation
- Comparison of impacts using different methodologies
- Impact of disposal methodology
- Comparison of impact of different dredging and disposal methodologies
- Hydrodynamics of the dredged area

3. *Sensitivity of the receiving environment*

- Conservation status e.g. Natura 2000 site
- Sensitive species
- Bioaccumulation potential
- Harvesting of commercial species (e.g. fish / shellfish)
- Hydrodynamics

Table 1.3 (below) indicates how these factors are integrated in a phased process.

Before a Dumping at Sea permit can be granted, the assessment must demonstrate that there is no unacceptable ecological risk associated with the disposal operation.

The assessment will identify critical stressors (sources of potential adverse impact e.g. toxicity, habitat alteration) and critical receptors (species or habitats of importance in terms of ecosystem, commercial interest or stakeholder concern). An attempt will also be made to elucidate relationships between the stressors and receptors. In theory, it is preferable to apply numerical values to all lines of evidence to give an overall quantitative result. In reality, this may prove too cumbersome for assessment purposes and so the relative significance of each line or factor will be expressed qualitatively. Taking into account this information, best professional judgement (Burton *et al*, 2002) will be applied in identifying the best environmental option, or preferred management option, for the disposal of the material concerned.

All relevant factors will be considered in the assessment process, for instance, anomalous results (single sample with elevated concentrations), localised patches of contamination and possibilities for isolating the most serious contaminants e.g. TBT[10].

While the WoE approach uses many additional lines of evidence not previously considered under the former *Provisional Action Levels* process, it does not eliminate uncertainty in reaching conclusions. It is, nevertheless, a means of weighing and comparing the respective environmental risks associated with different actions and, in the present case, disposal options.

In cases where scientific evidence is insufficient, inconclusive or uncertain and where preliminary scientific evaluation indicates that that there are reasonable grounds for concern about potentially harmful effects on the environment, it is intended to adopt *the precautionary approach*[11]. This may sometimes result in rejection of a particular option for dredging or dredged material disposal.

It is important to stress that each case will be considered individually on its merits, using a pragmatic and equitable approach to weighing the consequences of different management options. Efforts will also be made to compare the overall environmental costs of alternative disposal methods in determining the best environmental option.

1.9.2 Phasing the assessment

The proposed strategy for the assessment of sediments involves a 3-phased approach, as indicated in Figure 1.1. The two sets of guidance values (upper and lower) will aid the assessment. These levels are similar to the cut-off points between categories in the former provisional levels.

In effect, the system will work as a classification system where sediments with concentrations less than level 1 will fall within class 1; sediments with concentrations between levels 1 and 2 will fall within class 2 while those above level 2 will fall within class 3.

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[10] TBT is an example of a substance whose contamination can be either widely dispersed (granular) or very localised (flakes). It is possible to have a small localised area of highly contaminated sediment while the surrounding sediments are clean.

[11] A concept, (thought to have originated in the FDR), intended to prevent environmental degradation; incorporated into article 2 of the OSPAR Convention 1992 and the Rio Declaration, 1992.

These categories, or classes, can be described as follows:

***Class 1**:*
- Contaminant concentrations less than level 1.
- Uncontaminated: no biological effects likely.

***Class 2**:*
- Contaminant concentrations between Level 1 and Level 2.
- Marginally contaminated;
- Further sampling & analysis necessary to delineate problem area, if possible.

***Class 3**:*
- Heavily contaminated;
- Very likely to cause biological effects / toxicity to marine organisms.
- Alternative management options to be considered.

Phase 1 is effectively an initial screening step, making use of available records. Information required for this initial assessment will include:

- the quantity of sediments to be dumped at sea;
- the area to be dredged;
- approximate granulometry (preferably based on borehole samples);
- appropriate local historical data and information on pollution sources;
- availability of recent (within 5 years) sediment chemistry data indicating the contaminant load to be in Class 1;
- ecological sensitivity of receiving environment.

If this assessment indicates that no ecological risk (apart from physical impact) is expected as a result of the disposal operation, then the material will be considered suitable for disposal at sea. However, in the absence of adequate information (scientific or otherwise) to make such a judgement, *Phase 2* testing will be required.

Further chemical testing will be requested in Phase 2. Ecotoxicological testing may also be requested, depending on the individual case. A sampling and analysis plan will be drawn up by the MI for each site. Phase 2 information will be assessed by reasoned judgement. Should phase 2 testing indicate several samples with contaminant levels in Class 2, or Class 3 (Figure 1.1), then *Phase 3* testing will be required.[12]

Phase 3 aims to identify and delineate the problem area and to ascertain whether any of the material could be considered suitable for dumping at sea. Phase 3 will involve further sampling and chemical analysis and ecotoxicological testing. The selected test type will be dependent on the type of contamination.

In Phase 3 assessments particular attention may be given to ecotoxicological /biological characteristics as these can give a better indication of potential risk than available chemical data. In specific cases other information may be required to aid the assessment, e.g. biological effects, such as *imposex*[13] in gastropods and benthic community analysis.

The assessment process is summarised in Figure 1.1, including the proposed WoE approach and assessment criteria.

Shipping activity in Galway Harbour

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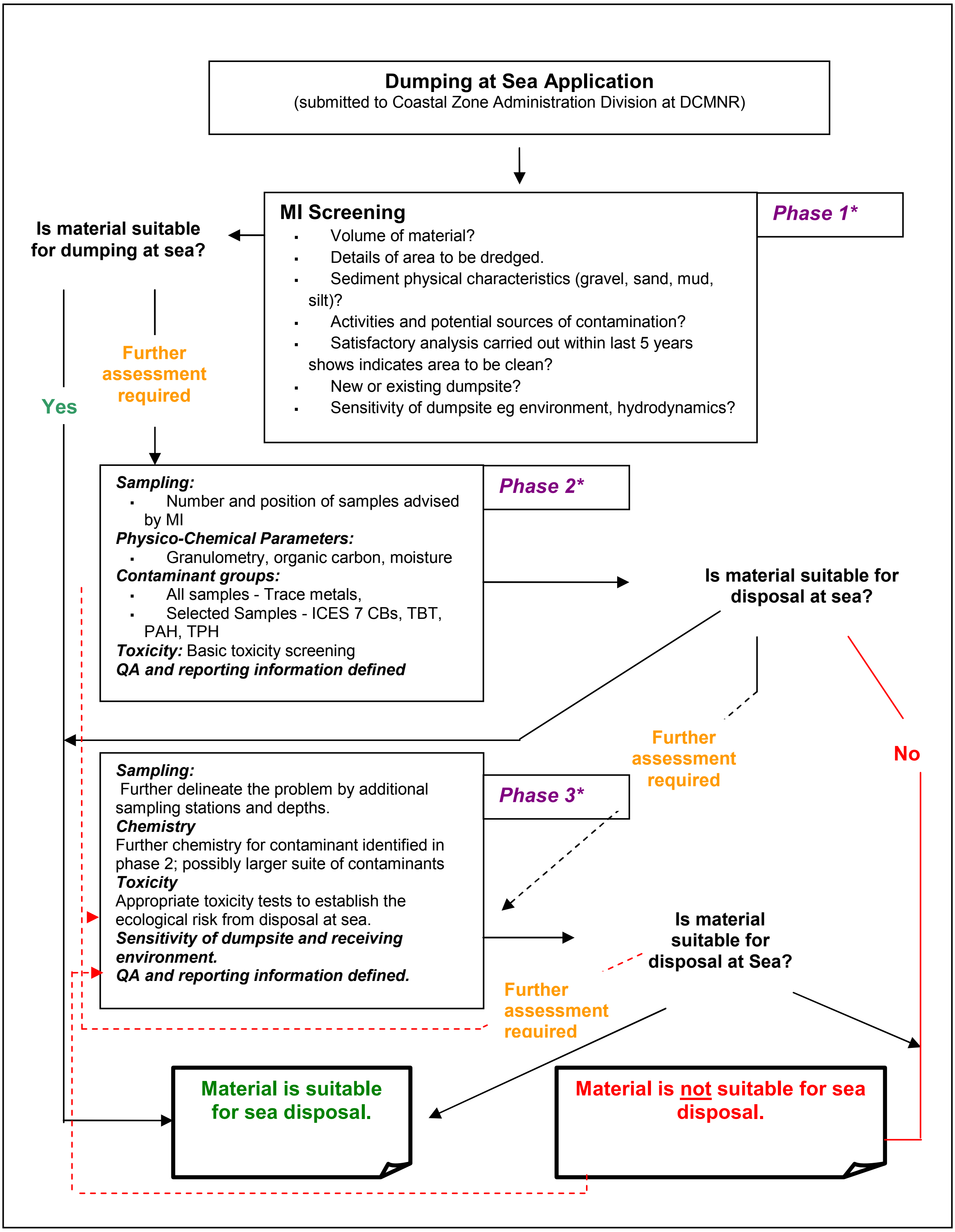
[12] In cases where localised areas of contamination (hotspots) exist, e.g. TBT contamination resulting from paint flakes, dredging of **non-impacted** areas may be allowed to proceed, pending phase 3 analysis.

[13] The occurrence of induced male sex characteristics superimposed on normal female gastropods, with the development of male sex organs.

Table 1.3 Factors to be included in weight of evidence approach

Phase	**Assessment factors**
1	⇨ Is quantity <5 000 m^3? ⇨ Is dredge area free of potential local sources of contaminants (pressures)? ⇨ Is dredge material composed mainly of sand, gravel or rock? ⇨ Do recent analyses indicate low levels of contamination? ⇨ Has dumpsite been previously used?
If predominantly NO answers, then proceed to phase 2.	
2	⇨ Is volume to be disposed of > 5000 m^3? ⇨ Is material predominantly silt? ⇨ Is there a possibility of radiological hazard associated with the material? ⇨ Are concentrations of contaminants greater than the lower guidance level? ⇨ Are the concentrations of contaminants greater than the upper guidance level? ⇨ Are elevated concentrations explainable by factors other than: ⇨ nature of sediment, e.g. organic content, grain size, or ⇨ existing or historical local sources? ⇨ Is sediment toxic to marine organisms? ⇨ Do particular sensitivities exist at dumpsite e.g. proximity to SAC, harvesting of commercial species, fish spawning beds, nursery grounds?
If predominantly YES answers, then proceed to phase 3.	
3	⇨ Is further chemistry required e.g. additional sampling (spatially and sub-surface), larger suite of parameters? ⇨ Is other information required e.g. state of benthic community? ⇨ Do concentrations exceed upper guidance levels? ▪ Which substances? ▪ By how much? ▪ In how many samples? ▪ In what locations? ⇨ Contaminant loads for disposal? ⇨ Is sediment acutely toxic to marine organisms? ⇨ Should a particular dredging/disposal method be recommended? ⇨ Is there risk due to increased bioavailability over time?
If predominantly YES answers, then iterative step to phase 3 testing likely, or alternative options to be sought.	



Dumping at Sea Application
(submitted to Coastal Zone Administration Division at DCMNR)

MI Screening

- Volume of material?
- Details of area to be dredged.
- Sediment physical characteristics (gravel, sand, mud, silt)?
- Activities and potential sources of contamination?
- Satisfactory analysis carried out within last 5 years shows indicates area to be clean?
- New or existing dumpsite?
- Sensitivity of dumpsite eg environment, hydrodynamics?

Is material suitable for dumping at sea?

Sampling:

- Number and position of samples advised by MI

Physico-Chemical Parameters:

- Granulometry, organic carbon, moisture

Contaminant groups:

- All samples - Trace metals,
- Selected Samples - ICES 7 CBs, TBT, PAH, TPH

Toxicity: Basic toxicity screening

QA and reporting information defined

Is material suitable for disposal at sea?

Sampling:
Further delineate the problem by additional sampling stations and depths.
Chemistry
Further chemistry for contaminant identified in phase 2; possibly larger suite of contaminants
Toxicity
Appropriate toxicity tests to establish the ecological risk from disposal at sea.
Sensitivity of dumpsite and receiving environment.
QA and reporting information defined.

Is material suitable for disposal at Sea?

Material is suitable for sea disposal.

Material is not suitable for sea disposal.

Figure 1.1 Assessment of sediments with respect to chemical contamination for disposal at sea permit. * indicates case specific route. - - - - indicates iterative step.

1.10 Interpretation of results

The lower level guidance values correspond to contaminant concentrations below which the sediment, if disposed of at sea, is assumed to have a physical impact only. The upper level guidance values are set at concentrations above which adverse effects might be expected.

Lower level guidance values represent concentrations that are either a) at the upper end of the no-effect range or b) at background concentrations. Upper level guidance values are set at the lower end of the known range of effective concentrations i.e. lowest concentrations shown to have adverse effects on marine organisms.

Comparisons between guidance values and measured concentrations of contaminants will determine subsequent assessment and/or management requirements. Actions stemming from such comparisons could include, for example, estimation of associated toxicity, delineation of a contaminated area or decisions on the fate of the sediment.

1.10.1 Chemistry

1.10.1.1 Normalization

Where appropriate and feasible, other factors such as normalization will also be taken into account in the assessments. Normalization is a procedure that corrects contamination levels for natural differences in sediment composition, thus improving the basis for comparison between different sediment samples. Normalisation with a conservative element such as lithium, aluminium or iron may also help to identify areas with naturally high background levels of certain metals (*See also 2.5*).

The reason for normalising with co-variables relates to the binding capacity of sediments and to the content of fines in that sediment. Co-variables commonly used are particle size, organic carbon, and conservative elements such as aluminium and lithium.

1.10.1.2 Grain size

Most contamination is associated with the fine fraction of the sediments. Clay minerals (<2µm fraction) have ionic charges resulting in strong cohesive forces that bind most heavy metal and organic contaminants. As a result, concentrations should generally be corrected for the amount of fine material in the sediment.

1.10.1.3 Aluminium / Lithium

Aluminium and lithium are metals occurring in abundance in the Earth’s crust. They are conservative elements and are rarely elevated as a result of pollution. Aluminium is a major constituent of the clay fraction, while lithium is enriched within that fraction. A fairly constant ratio exists between aluminium and other metals, and between lithium and other metals, thus making them suitable as normalizers to identify artificially elevated concentrations of metals.

1.10.1.4 Organic carbon

Organic contaminants and, to some extent trace metals, bind to the organic fraction of sediment (e.g. humus), and therefore elevated levels would be expected in organic carbon-rich sediments. The higher the organic carbon content, the greater the capacity for reducing the availability of the contaminant; this may be taken into account in an assessment.

1.10.2 Toxicity

The interpretation of toxicity test results will depend on various factors, such as the test type and choice of organism, as well as the degree of toxicity found.

The types of test to be carried out will; depend on the basis of the nature and degree of contamination and the biological responses of concern. Acute toxicity (lethality) exerted by contaminants in marine sediments can be measured using one of the following methods:

- Inhibition of bioluminescence in *Vibrio fischeri* (Microtox solid phase test)
- 10 day whole sediment bioassay (amphipod survival test);

- Water bioassays (porewater, elutriates, seawater bioassays on *Ostrea* embryos, *Tisbe*, etc)
- 14 day whole sediment *Echinocardium* survival and reburial test;
- Microtox aqueous-phase test (pore waters, elutriates, seawaters)

If chronic (sub-lethal) toxicity is suspected, it can be measured in terms of biological effects such as in the following:

- Reproductive success (of fish)
- Burrowing activity (in *Arenicola*)
- DR Calux assay (for dioxin-like activity)
- Cytochrome P450 / EROD (biomarker for exposure to chemical contaminants)
- Imposex / intersex
- Metallothionein
- ER Calux assay (for oestrogen-like activity)

As a general rule, the greater the number and range of toxicity tests carried out, the greater the confidence will be in the toxicity assessment. Laboratory tests do not precisely simulate field conditions and the sensitivity of different tests may vary widely. Accordingly, suites of tests will be preferred to single tests.

Test results are expressed in different ways depending on the test carried out. Microtox results are usually quoted in toxic units (TUs); TU = 100 divided by the concentration of test substance (in %) that reduces bioluminescence by half during the exposure period i.e.100/EC_{50}. The higher the TU value, the greater the toxicity. A single toxicity unit would signify a marginal, and perhaps negligible, level of toxicity while 3 TU might suggest some potential for effects in the marine environment (R.Hernon, pers comm.).

The results of acute tests with marine invertebrates are typically expressed as the percentage of animals affected under standardized conditions of exposure e.g. percent mortality in 48 hours. Control exposures, either to contaminant-free sediment or sediments from clean reference sites, must be included in the tests. The results of control exposures are taken into account in reporting test results. As a guide, a result of < 20% mortality may be deemed not to pose a substantial risk, while > 80% mortality would classify the sediments as being acutely toxic (Boelens, pers comm.). Subject to other lines of evidence, samples yielding results that fall between these values may require further testing.

1.10.3 Class 2 sediments

Management of sediments with chemical concentrations that place them in Class 2 may be extremely complex. It is intended to take a pragmatic approach to these sediments using alternative lines of evidence to more accurately determine the hazards they present. The type and level of contamination will be considered, for instance: Which chemicals are elevated, by how much, how many samples demonstrate contamination? It may also be pertinent to consider whether it is more appropriate to rate the degree of contamination in terms of concentration or mass of contaminant. All decisions regarding Class 2 sediments will be based on best professional judgement.

1.10.4 Sensitivity of the dumpsite

Depending on the nature and/or quantity of dredged material and the type of substrate and its associated marine communities, a dumpsite may be considered sensitive. Proximity to sites such as Marine Nature Reserves, Special Areas of Conservation, sensitive ecosystems, protected species or marine archaeological sites may increase the sensitivity rating. A sediment that is acceptable for disposal at a less sensitive site, may be prohibited at a sensitive site.

The hydrodynamics at around dumpsites are also important considerations as sediment transport at dispersive sites can result in material settling at a distance from where it was released.

1.11 Management options following assessment

It is current DCMNR policy that alternative land-based disposal options and/or beneficial reuse of the material have been examined fully and that dumping at sea is the only reasonable option. For clean material, re-use is the preferred option. Options such as beach replenishment with sand, use in future building projects and land reclamation should also be considered. Where the dredge material is clean coarse material, and a local re-use option exists (e.g. building works or coastal defence work) it is unlikely that a dumping at sea permit will be issued.

In other cases, depending on the outcome of the assessment, a permit may be granted for sea disposal of dredged material. This may include all or part of the dredged sediments referred to in the Dumping at Sea application.

Invariably a number of conditions and/or requirements will be attached to a Dumping at Sea permit. Examples are:

- Baseline monitoring of turbidity at dumpsite and nearby sensitive areas;
- Monitoring of turbidity during dumping operations;
- Dumpsite hydrodynamic survey;
- Full dumpsite survey;
- Periodic post-dumping turbidity monitoring;
- Capping of material with clean sand;
- Bunding of the disposal area.

In cases where sediments are heavily contaminated, it is unlikely that dumping at sea will be permitted. In such cases, alternative management and disposal options will be considered including:

- *In-situ* burial of the sediments;
- *Ex situ* / deep sea burial;
- Remediation / bioremediation of contaminated sediments;
- Separation of clean and contaminated materials (e.g. hydro-centrifugation);
- Vitrification of contaminated material;
- Use of leach-proof containers for seabed placement;
- Confined disposal facility (e.g. the Schlufter in Rotterdam);
- Trans-frontier shipment for incineration.

The case study below provides an example of an alternative sediment management strategy where dumping at sea had been prohibited owing to the heavy contaminant load within the dredge material.

1.12 Worked case example

History:

A port company sought to dredge 250 000 tonnes of sediment to accommodate large draft vessels at a disused berth. The proposed dredging area measured approximately 200m by 100m, and was from 3m up to 11m deep. Earlier borehole sampling at the edges of the dredging area indicated that the material comprised up to 62% rock/gravel, up to 40% sand and up to 20% silt.

The initial application was evaluated (*Phase 1*) and, based on historic pollution information, MI drew up a detailed sampling and analysis plan for *Phase 2* of the assessment.

Problem:

Using the *Provisional Irish Action Levels* as a guide, and levels from other countries, in this instance the Netherlands and Norway, *Phase 2* test results were assessed. Sediment chemistry indicated pockets of lead contamination (understood to be from historic export activity at the port) where the concentration exceeded *Action Level 2*, and therefore fell within *Class 3*. High levels of polycyclic aromatic hydrocarbons (PAHs), from an unknown source, were also detected. No other trace metals or organochlorine substances were present in any samples at levels that would preclude disposal at sea, i.e. other contaminants were ranked as being within *Class 1*, or below the *lower guidance values,* for the remaining parameters. The area of contamination appeared to be almost wholly contained within the western half of the dredge area and to occupy approximately one quarter of the total dredging area.

Phase 3 testing was brought into operation. In discussion with the port company management, MI devised a detailed sampling plan in order to delineate the problem zone. Sampling was to be carried out at smaller intervals, at the surface and at a depth of 1m. The depth of 1m was chosen because borehole data for the area showed that the silt layer rarely exceeded 1m. In addition to chemical analyses, ecotoxicological testing was also requested. Three samples were tested by the Microtox bioluminescence method (which uses *Vibrio* as the test organism),and three samples were subjected to 10-day whole sediment bioassay using the amphipod *Corophium*.

Results of the *Phase 3* chemical testing indicated that the elevated lead was an isolated incident but that the PAH concentrations fell within *Class 3*. Toxicity tests showed that the sediments were acutely toxic with inhibited luminescence in the Microtox tests and up to 100% mortality in the amphipod tests. The port company suggested carrying out core sampling in order to assess the actual depth and location of the silt layer in the contaminated zone, and thus to quantify the contaminated sediments.

Solution:

Chemical analyses and ecotoxicological tests on grab and core samples demonstrated that the contaminated zone was limited to an area 105m (east/west) by 60m (north/south) in an area running east-west in the middle of the proposed dredge area. The silt layer was 1.2m thick at maximum giving a volume of approximately 6 300m^3 of sediment to be excluded from the material to be dumped at sea.

The port company met for discussion with MI and DCMNR Engineering Division to agree on a way forward. Having considered all available options, it was agreed that the best environmental option was containment of contaminated sediments under the berth, thereby retaining the sediment within its original area of contamination, within a low energy site where it is unlikely to be disturbed.

This would be achieved by over-dredging an area within the uncontaminated zone, followed by dumping and capping of the contaminated sediments with clean material. The company produced a method statement for digging an enclosure pit, which included the following points:

- Use of an “Eco-grab” which allowed contaminated sediments to be moved in a way that minimised disturbance and prevented overflow
- Dredging the area of contamination by using an agreed method
- Storage of contaminated sediments in barges
- Pit to be of a size to contain all contaminated sediments
- Pit to be dredged to a depth that would allow 2m of clean material on top
- Side-slopes to be such that slippage would be prevented

Aside from some engineering difficulties encountered (and resolved), the operation went according to plan, and the solution was satisfactory to the DCMNR, the port company and the MI. The remaining clean sediments were dumped at sea.

Section 2: Sampling, analysis and quality assurance

2.0 Introduction

This section sets out general guidelines for sample acquisition, storage, pre-treatment, analytical methodology and reporting of results.

The Marine Institute advises permit applicants on sampling strategy and test requirements on a case-by-case basis. Applicants are advised to contact the Marine Institute early in the process.

2.1 Sampling protocol

Samples are to be taken under the direction of the analysing laboratory at locations selected by MI. Numbers of samples will at least meet the OSPAR guidelines for management of dredged material, which recommends the following:

Volume to be dredged (m^3)	No. of samples
Up to 25 000	3
25 000 – 100 000	4 - 6
100 000 - 500 000	7 - 15
500 000 - 2 000 000	16 - 30
>2 000 000	Extra 10 per million m^3

For small dredging projects (<5 000 m^3), analysis may not be required. In locations known to be heavily contaminated, additional samples will be required in order to delineate the area of contamination. Typically, sampling will focus on the location with the greatest likelihood for contamination but sufficient samples should be taken to ensure adequate coverage of the entire area to be dredged.

The sampling procedure should not unduly alter the properties of the sediment e.g. contamination, surface layer. The choice of sampling device (e.g. box corer, grab) will depend on the analysis required (biology or chemistry) and on local conditions (water depth, type of sediment). Stainless steel sampling devices should be used for samples requiring analysis for metals.

Generally, only surface samples are requested. However, depending on circumstances, it may be necessary to take sub-surface samples. For capital projects, initial site investigation often requires boreholes. It may be expedient to take subsurface samples at this stage to avoid necessity of duplication of such sampling. In such cases it is important to contact MI to ensure appropriate samples are taken and that sampling and analytical procedures are ‘fit for purpose’.

Samples should be of a size that allows ample material for analysis. Testing should be carried out on the <2mm fraction. Most of the contaminant burden resides in the fine fraction, which may be a relatively small proportion of the total sediment. Therefore it is important to ensure that sufficient sample is taken.

Toxicity testing can require large amounts of sample, so if it is suspected that toxicity testing may be required in future, it is best to take adequate sample volumes initially, as re-sampling can be expensive. (If chemical analysis is carried out to determine the impact at a dumpsite, it may be appropriate to analyse the fine fraction of <63µm)

Sampling is a critical part of the testing procedure. In order to minimise sampling errors, the following procedures are recommended to ensure the integrity of the samples:

- Sampling should be carried out according to appropriate procedures by trained personnel, in liaison with testing laboratories;
- Appropriate gloves should be worn when sampling (e.g. powder free vinyl or nitrile);
- Samples should be taken of surface sediment, away from sides of sampler (i.e. in the centre of the core or grab sample);
- All sample containers and foil lid-liners should be acid washed for metals, and solvent rinsed for organics.
- Sample jars should be labelled with sample identity, date, position, sediment depth and water depth. These details should also be logged on sample sheets.
- In the absence of freezer space, samples may be kept in the dark in a fridge or cold-room for

up to 48 hours. (See Table 2.1 for detailed information.)

Sediment sampling using a Reineck box corer

For general information regarding sampling and testing of sediments see the OSPAR Joint Assessment and Monitoring Programme (JAMP) guidelines for monitoring contaminants in sediments (OSPAR, 1997). ISO/CEN also provide methodology for sampling and testing. A list of relevant guidelines can be found in Annex 9.

2.2 Parameters for analysis

Parameters required for analysis will be decided on a case-by-case basis, taking into account location, local pollution sources, pressures and sensitivities. However, based on recommendations from the OSPAR guidelines on the management of dredged material (OSPAR, 2004), testing for all samples will include:

- granulometry
- organic carbon
- heavy metals
- TBT / DBT

Depending on local sources, data on PCBs, PAHs and other parameters may be requested. Toxicology tests may also be required, for example if previous analysis has indicated high levels of contamination.

The toxicity test(s) required will be greatly influenced by the nature of the contaminant, for example whether the chemical is hydrophobic or hydrophilic, as well as the types of sediment and community at the dumpsite.

The test species employed will also be influenced by the possible uptake routes for the organisms e.g. infaunal organism, deposit or suspension feeding. Inhibition of bioluminescence in the Microtox test is not necessarily a good indication of lipophilic organic contaminants.

In exceptional cases, as part of a management decision, it may be necessary to carry out a toxicity identification evaluation (TIE) to isolate the cause of toxicity from a mixture. TIE involves the manipulation of a sample in order to reduce the bioavailability of different components, for instance pH adjustment controlling pH sensitive compounds (sulphides), chelating of cationic metals (copper, zinc, cadmium) and removal of non-polar compounds (some pesticides) through solid phase extraction.

Annex 5 shows an example of instructions that will be provided by MI on number of samples and analysis required. Analysis of some parameters may not be necessary for sediments with large grain size only (e.g. > 2mm), or where dredging is to be carried out far from point /anthropogenic sources of pollution

2.3 Analytical method selection and performance

It is not the intention to be over-prescriptive concerning analytical methods. However, methods should meet a certain minimum level of performance to ensure that subsequent decisions are based on results that are reliable and 'fit for purpose'. Guidance is given concerning method selection, particularly for parameters that are defined by the analytical method, for example Total Petroleum Hydrocarbons (TPH).

Table 2.1 Guidelines for sampling / storage of sediments for chemical analyses (from OSPAR JAMP guidelines for monitoring contaminants in sediments.)
These are general guidelines. Alternative approaches may be used if assessed and validated.

Analysis	Container	Sampling procedure	Container preparation	Transportation	Storage
Organic Carbon	➢ Glass ➢ Polyethylene ➢ PTFE ➢ Plastic	➢ Clean plastic/PTFE equipment, or stainless steel grab/corer.	➢ Containers should be clean.	➢ Transport preferably in cool-boxes	➢ Can be refrigerated for short-term ➢ Should be dried or frozen if imminent analysis is not expected within 1 month
Metals	➢ Glass ➢ Plastic ➢ PTFE	➢ Clean plastic/PTFE equipment, or stainless steel grab/corer. ➢ Avoid sample within 1 cm of sampler wall ➢ Sample should be sieved to < 2mm as soon as possible after sampling	➢ Jars should be acid washed.	➢ Transport cool	➢ Samples may be refrigerated for several weeks ➢ Samples may be frozen / freeze–dried then milled / homogenised for prolonged storage,
Mercury	➢ Glass ➢ Quartz ***Plastics must not be used***				➢ Samples should be frozen (<-20°C)
Polycyclic aromatic hydrocarbons (PAH)	➢ Glass (Darkened) ➢ PTFE ***Plastics must not be used***	➢ PTFE equipment or stainless steel grab/corer. ➢ Avoid sample within 1 cm of sampler wall ➢ Sample should be sieved to < 2mm as soon as possible after sampling	➢ Jars should be detergent washed and solvent rinsed. ➢ Lids should be lined with solvent washed foil	➢ Transport cool in light protected closed containers	➢ If analysis not carried out within 48hrs, can be refrigerated short-term ➢ Should be frozen if analysis is not expected within 1 month ➢ Must be stored in the dark
Organochlorine contaminants	➢ Glass ➢ PTFE ***Plastics must not be used***		➢ Jars should be solvent rinsed. ➢ Lids should be lined with solvent washed foil.	➢ Transport cool in closed containers	➢ Freeze / Freeze – dry
TBT / DBT / MBT	➢ Glass (Darkened) ➢ Polycarbonate ➢ Aluminium		➢ Jars should be acid washed and solvent rinsed.	➢ Transport cool in light protected closed containers.	➢ If analysis not carried out within 48hrs, can be refrigerated ➢ Can be stored dried or frozen for a year or more. ➢ Must be stored in the dark
Bioassays	➢ Darkened container	➢ PTFE equipment or stainless steel grab/corer.	Containers should be clean.	➢ Transport cool in closed containers	➢ Keep cool ~ 4^oC for analysis within 48hrs. Otherwise, should be frozen. ➢ Must be stored in the dark

2.3.1 Method validation

Analysing laboratories should have information on the performance of the analytical method with respect to its:

- trueness/accuracy;
- precision;
- limits of detection (LoD) and limits of quantification (LoQ)[14];
- robustness.

2.3.2 Limit of detection (LoD) and limit of quantification (LoQ)

It is essential that laboratories and analytical methods should be capable of producing reliable results at concentrations below the lower guidance level values .

The required detection limits for the various determinants are set out in Table 2.2 below. The analysing laboratory should be capable of achieving these detection limits, under normal sample conditions. It is accepted that these LoDs may not be attainable with every analysis; for instance, if the sample requires substantial clean-up.

Table 2.2 Limits of detection required to be met by laboratories for the analysis of sediments for a Dumping at Sea permit.

Contaminant	Concentration	Units (dry weight)
Mercury	0.05	mg kg^{-1}
Arsenic	1.0	mg kg^{-1}
Cadmium	0.1	mg kg^{-1}
Copper	5.0	mg kg^{-1}
Lead	5.0	mg kg^{-1}
Zinc	10	mg kg^{-1}
Chromium	5.0	mg kg^{-1}
Nickel	3	mg kg^{-1}
Total extractable hydrocarbons	10.0	mg kg^{-1}
TBT and DBT (not organotin)	0.01	mg kg^{-1}
DBT	0.01	mg kg^{-1}
PCBs (individual congeners)	0.5	µg kg^{-1}
DDE pp	0.5	µg kg^{-1}
DDT pp	0.5	µg kg^{-1}
DDD pp	0.5	µg kg^{-1}
Dieldrin	0.5	µg kg^{-1}
Lindane	0.5	µg kg^{-1}
HCB	0.5	µg kg^{-1}
PAHs	20	

2.3.3 Guidance on analytical methods

Guidance on specific analytical methods can be found within the OSPAR JAMP guidelines (OSPAR, 1997) for monitoring of contaminants in sediments

(a) Total petroleum hydrocarbons (TPH): TPH is a method-specific parameter; different methods can produce different results for the same sample as measurements are based on different properties. Options for analysis are:

- Gravimetric;
- Gas chromatography;
- Infrared spectroscopy (IR) (solvent problems & aliphatic focussed),
- Fluorescence spectroscopy (UVF) (aromatic focussed),

IR spectroscopy determinations are based on the aliphatic hydrocarbon component; this method is now less used as it requires ozone depleting solvents. Fluorescence spectroscopic measurements are based on the aromatic hydrocarbon component. Acetone/hexane extraction and GC with flame ionisation detection (FID) is a preferred alternative to spectroscopic methods (e.g. Standard method – NEN 5733). The method used should be clearly indicated in the report.

(b) Total Organic Carbon (TOC): Loss on ignition, although a useful method, is not a measure of organic carbon but rather of organic matter. TOC is required for normalisation purposes. TOC can be measured using an elemental (CHN) analyser or TOC analyser using an appropriate

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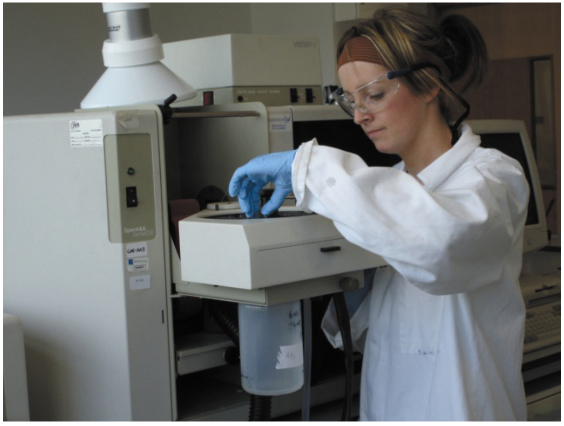
[14] LoD: The lowest quantity of an analyte in a sample that can be detected, but not necessarily quantified under the stated conditions of the test.
LoQ: The lowest concentration of an analyte that can be determined with acceptable precision and accuracy under the stated conditions of the test.
(NATA Tech note#13, cited in Eurochem, 1998.

extraction technique, or by wet chemical methods –- Carbon analyser @ 1300°C – (Standard method –NEN 5756).

(c) Carbonate: Carbonate content gives an indication of the biogenic content of a sediment, and can also be useful in determining the source of the sediment because most carbonate sediments are of marine origin. Carbonate can be analysed by classic wet or instrumental techniques.

(d) Trace metals: While partial digestion yields solutions that are more indicative of bioavailable concentrations of metals, for comparability of data it is considered appropriate that total digestion techniques, or at least strong partial digestions, should be employed. Note that most quality assurance tools, such as certified reference materials (CRMs) and laboratory proficiency tests (LPTs) are based on total measurements. This is also the case for threshold effect concentrations against which analytical results will be rated. For some metals (e.g. chromium), measured concentrations may be lower if a partial digestion is used and assessments should account for this.

Appropriate element specific methods of determination, that give the desired level of detection (e.g. graphite furnace atomic absorption spectroscopy, inductively coupled plasma – mass spectrometry (ICP-MS), atomic fluorescence), should be employed.



Analysis of sediment by Atomic Absorption Spectroscopy

(e) Organotins: Various procedures can be used for measurement of organotins. The preferred method involves extraction and derivitisation of organotins with Grignard reagent or sodium tetraethylborate. Determination should be by GC with selective detection such as pulsed flame photometric detection (PFPD), MS, ICP-MS or GFAAS.

(f) Organochlorine contaminants: Following appropriate extraction and sample clean-up steps, suitably specific and sensitive methods of extraction, separation and detection should be employed to determine concentrations of individual contaminants/congeners (e.g. gas chromatography with electron capture detection (GC-ECD), or gas chromatography–mass spectrometry (GCMS).

(g) Polyaromatic hydrocarbons (PAH): Following appropriate extraction and sample clean-up steps, suitably specific and sensitive methods of separation and detection should be employed to determine concentrations of individual PAH compounds. Both high performance liquid chromatography (HPLC) with fluorescence detection and GCMS are routinely used for this purpose. Where direct petroleum inputs, rather than runoff or combustion related sources, are expected to predominate, GCMS is preferred as it has a greater ability to distinguish petrogenic PAH (e.g. alkylated PAH). Where the source is unknown, GCMS can also provide information on whether pyrogenic or petrogenic sources predominate.

(h) Bioassays: Acute toxicity exerted by contaminants in marine sediments can be measured using one or more of the following methods:

Inhibition of bioluminescence in *Vibrio fischeri* (Microtox solid phase);

- 10 day whole sediment bioassay (amphipod survival test);
- Water bioassays (porewater, elutriates, seawater bioassays on *Ostrea* embryos, *Tisbe*, Microtox etc);
- 14 day whole sediment *Echinocardium* survival and reburial test.

If chronic toxicity is suspected, it can be measured in terms of selected biological responses such as the following:

- Reproductive success
- Burrowing activity in *Arenicola*
- DR Calux assay for dioxin-like activity
- EROD
- Cytochrome P450
- ER Calux assay for oestrogen-like activity

2.3.4 Quality Assurance (QA) Requirements

Appropriate marine certified reference materials (CRMs) or other reference materials (e.g. in-house reference materials) should be included in each batch of analyses and the results reported along with sample determinations (See de Boer and Mc Govern, 2001, for assessment of appropriate CRMs and / or other reference materials). Certified and assigned reference values should also be included in the report. Where substantial quantities of potentially contaminated material need to be assessed, replicate analyses may be required.

There is a number of proficiency testing schemes (PTS) available that incorporate sediments. One example is QUASIMEME (Quality Assurance of Information for Marine Environmental Monitoring). QUASIMEME includes almost all of the required determinants in marine sediment samples and is carried out on a biannual basis. Another scheme is the Water Research Centre (WRC) Aquacheck scheme. Aquacheck provides proficiency testing samples and services for the analysis of organic and inorganic chemicals in sediments and soils. It is preferred that laboratories participate regularly in such schemes and that results be available for inspection.

If a method is accredited to an internationally recognised norm, such as ISO 17025, this indicates a quality assurance programme is in place. It is still necessary to ensure that the method fulfils the requirements set out above (e.g. appropriate detection limits).

The Biological Effects Quality Assurance in Monitoring Programmes (BEQUALM) project offers a number of QA measures for biological effects testing. It plans to make available appropriate reference materials and procedures.

2.4 Frequency of analysis

Decisions on sampling frequency will be made on a case-by-case basis.

Sediment analysis may not be required if testing carried out in the previous 3-5 years indicated the dredge material was essentially "clean" and there are no known point sources of contaminants nearby and no other likely causes of deterioration. Distance from a pollution source, or absence of local industrial activity, does not however preclude contamination.

Within five years of a comprehensive sediment survey, even if the area is known to be subject to various pressures, it may be sufficient to carry out a reduced sampling plan. However, if results of the reduced plan reveal substantially elevated levels of contamination, it will be necessary to carry out further sampling to define the extent of that contamination. Some applicants may prefer to carry out a thorough initial investigation, as it will generally minimise the application processing time.

2.5 Normalisation

Normalisation is the procedure for correcting contamination levels to account for natural differences in sediment composition. Primarily this is based on grain size as contaminants tend to be associated with the fine fraction. Normalising with co-variables is based on the binding capacity of sediments and is related to the content of fines in that sediment. The parameters used for standardisation of natural variability include particle size, aluminium or lithium, and organic carbon.

The most common methods of normalisation are linear regressions or normaliser ratio calculations. Alternatively, isolation of the fine fraction can be regarded as physical normalisation. The normaliser ratio calculation is a straightforward method that involves setting guideline values for sediments based on either a particular organic content or granulometry, for example 10% organic matter content or 20% of material < 63 µm. The value could be adjusted to account for organic matter or % fines content higher or lower than these values. Where the gravel fraction (> 2mm) constitutes a significant part of the total sediment, this should be taken into account in the calculation of the concentrations.

2.6 Approval of laboratories for Dredged Material Testing

To ensure the appropriate quality of analytical results submitted, a system of approval for analytical laboratories will be put in place. This will be a relatively simple system, based on a questionnaire to be completed by the laboratories, to ensure that basic criteria are met for the tests required of them. The system is not intended to limit the choice of laboratories available to port authorities and/or dumping at sea applicants. Rather, it is intended to ensure cost benefits by reducing the need for re-analysis (e.g. because methods used do not meet the requirements) and thereby avoiding potential delays in processing applications.

Laboratory analyses of sediment samples

Laboratories will be approved on the basis of their response to a questionnaire (Annex 10) focussing on the following aspects of the proposed tests:

- relevant experience of the laboratory
- quality assurance
- methodology and performance characteristics

Where tests are subcontracted, the subcontracted laboratory must also be approved. Should an applicant wish to use an unapproved laboratory, the questionnaire should be completed and approval obtained in advance. However, should an unapproved laboratory have been used without prior consultation, the questionnaire may be completed and approval considered retrospectively.

A list of approved laboratories will be compiled showing the tests for which they are approved indicated. The list will be updated on an ongoing basis. If MI is not satisfied that laboratories meet the minimum requirements, re-analysis of parameters may be required.

Approval of a laboratory indicates that the laboratory meets a basic set of criteria in relation to testing of certain parameters in marine sediments. It does not infer that MI stands over the laboratory's results or that the Institute will necessarily be satisfied by tests or surveys performed by the laboratory. Furthermore, it does not constitute a general assessment of the competence of the laboratory concerned.

While it is desirable that laboratories be accredited for the tests in question, this is not an essential requirement providing they have appropriate experience and apply suitable methods and quality assurance procedures. Conversely, an accredited laboratory that does not meet these requirements will not be approved.

Approved laboratories may be removed from the list if significant problems are encountered with information reported to MI (e.g. inappropriate limits of detection). Approval will have to be re-granted before analytical results are accepted. For laboratories that do not routinely submit information for dredged material assessment purposes, the approval will be reviewed (questionnaire to be resubmitted) after a period of 2 years.

2.7 Reporting requirements

Reports of sediment analysis should include the following information:

- Date of sampling;
- Map clearly indicating the locations of samples
- Co-ordinates of sampling stations
- Sample information e.g. appearance, sample depth etc.;
- Treatment of samples and indication of sub sampling, compositing, storage etc.;
- Tabulated physico-chemical and chemical test results (hardcopy and electronic version. See annex 11);
- Full laboratory test results and analysis certificates;
- Results to be reported on dry weight basis
- Units to be clearly expressed;

- Summary method details, including digestion method / extraction and clean-up techniques and method of detection used;
- Accurate description of parameter e.g. TOC or loss on ignition
- Relevant QA information, including:
- Relevant scope of accreditation;
- Method performance specifications: Limit of detection, Precision, Bias;
- Batch QC (CRM) results and certified or assigned reference values.
- Chemistry and QA results to be submitted also in electronic format e.g. Excel file.

If a determinant is not detected, this should be stated and the LoD indicated.

All laboratories involved in testing should be clearly identified and a designated contact person nominated.

The information set out above is required from all laboratories, including subcontracting laboratories.

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Annexes

Annex 1: Glossary of acronyms:

AET–H	Apparent effects threshold – high
AET–L	Apparent effects threshold – low
AL	Action level
AMBI	
AVS	Available volatile sulphide
BEQUALM	Biological Effects Quality Assurance in Monitoring Programmes
BPJ	Best professional judgement
CEFAS	Centre for Environmental, Fisheries and Aquaculture Science
CTT	Chemical toxicity test
DBT	Di-butyl tin
DCMNR	Department of Communications, Marine & Natural Resources
DDT	Dichloro diphenyl trichloroethane
ERL	Effects range low
ERM	Effects range – median
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
ICES	International Council for Exploration of the Seas
IMO	International Maritime Organisation
Log K_{ow}	Log Octanol-Water Partitioning Coefficient is a measure of the equilibrium concentration of a compound between octanol and water that indicates the potential for partitioning into sediment organic matter (i.e., a high K_{ow} indicates a compound which will preferentially partition into sediment organic matter rather than water).
MBT	Mono-butyl tin
MI	Marine Institute
OCP	Organochlorine pesticide
OSPAR	OSPAR Convention
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PEL	Probable effects level
POP	Persistent organic pollutant
TBT	Tri-butyl tin
TEL	Threshold effects level
TOC	Total organic carbon
UCT	Uniform content test
USEPA	United States Environment Protection Agency
WFD	Water Framework Directive EC 2000. (Directive 2000/60/EC)
WoE	Weight of evidence

Annex 2: Provisional Irish action levels in mg kg^{-1} dry wt

Chemical	Category 1	Category 2	Category 3
As	<10	10-80	>80
Cd	< 1	1-3	>3
Cr	<100	100-300	>300
Cu	<50	50-100	>100
Hg	<0.3	0.3-0.5	>0.5
Ni	<50	50-200	>200
Pb	<50	50-400	>400
Zn	<400	400-700	>700
PCB 7	<0.01	0.01-0.1	>0.1
TBT	<0.1	0.1-0.5	>0.5
Total PCB	<0.1	0.1-1.0	>1

Annex 3: Commonly used biological effects guidelines.

ERL = effects range - low, ERM = effects range – median, AET-L – apparent effects threshold – low, AET-H – apparent effects threshold – high, TEL = threshold effects level, PEL = probable effects level.

		ERL	ERM	AET- L	AET-H	TEL	PEL
Arsenic	mg kg^{-1}	8.2	70	57	700	7.24	41.6
Cadmium	mg kg^{-1}	1.2	9.6	5.1	9.6	0.7	4.21
Chromium	mg kg^{-1}	81	370	260	270	52.3	160
Copper	mg kg^{-1}	34	270	390	1300	18.7	108
Lead	mg kg^{-1}	46.7	218	450	660	30.2	112
Mercury	mg kg^{-1}	0.15	0.71	0.59	2.1	0.13	0.696
Nickel	mg kg^{-1}	20.9	51.6			15.9	42.8
Zinc	mg kg^{-1}	150	410		1600		271
DDD pp	µg kg^{-1}	1.58	27	16	43	1.22	7.81
DDE op	µg kg^{-1}	2.2	27	9	15	2.07	374
DDE (pp')	µg kg^{-1}	2.2	27	9	15	2.07	374
DDT (pp')	µg kg^{-1}	1.6	27	34	34	1.19	4.77
Σ DDT	µg kg^{-1}	1.6	46.1	9	15	3.89	51.7
HCH Gamma	µg kg^{-1}						0.99
Hexachlorobenzene	µg kg^{-1}			22	230		
Anthracene	µg kg^{-1}	85.3	1100	960	13000	46.9	245
Acenaphthylene		44	640	1300	1300	5.87	128
Fluoranthene	µg kg^{-1}	600	5100	2500	30000	113	1494
Phenanthrene	µg kg^{-1}	240	1500	1500	6900	86.7	544
Pyrene	µg kg^{-1}	665	2600	3300	16000	153	1398
Benz-[A]-anthracene	µg kg^{-1}	261	1600	1600	5100	74.8	693
Benzo-[A]-pyrene	µg kg^{-1}	430	1600	1600	3600	88.8	763
Benzo-[ghi]-perylene	µg kg^{-1}			720	2600		
Acenaphthene	µg kg^{-1}	16	500	500	2000	6.71	88.9
Chrysene	µg kg^{-1}	384	2800	2800	9200	108	846
Dibenzo (ah) anthracene	µg kg^{-1}	63.4	260	230	970	6.22	135
Benzo(k) fluoranthene	µg kg^{-1}	280	1620	3600	9900		
Benzo(b) fluoranthene	µg kg^{-1}	320	1880	3600			
Naphthalene	µg kg^{-1}	160	2100	2100	2700	34.6	391
Fluorene	µg kg^{-1}	19	540	540	3600	21.2	144
Indeno-[1,2,3-cd]-pyrene	µg kg^{-1}	690	2600	690	2600		
PCB 028	µg kg^{-1}	22.7	180	1000	3100	21.6	189
PCB 052	µg kg^{-1}	22.7	180	1000	3100	21.6	189
PCB 101	µg kg^{-1}	22.7	180	1000	3100	21.6	189
PCB 138	µg kg^{-1}	22.7	180	1000	3100	21.6	189
PCB 153	µg kg^{-1}	22.7	180	1000	3100	21.6	189
PCB 180	µg kg^{-1}	22.7	180	1000	3100	21.6	189
PCB 118	µg kg^{-1}	22.7	180	1000	3100	21.6	189

AET legend

a	*amphipods*
b	*benthic organisms*
a + b	*amphipods & benthic organisms*
o	*oysters*
a + o	*amphipods & oysters*

Annex 4: Proposed new sediment guidance levels and comparisons with existing levels and ecotoxicologically-derived figures.

Threshold guidance level 1 values (mg kg^{-1}) for metals where background values are available.

	Value currently used as AL1	Value currently used as AL2	Levels derived using 95%ile of MI data	ERL	ERM
Cu	50	100	33	34	270
Pb	50	400	54	46.7	218
Hg	0.30	0.50	0.13	0.15	0.71
Cr	100	300	115	81	370
Zn	400	700	151	150	410
Cd	1.00	3.00	0.61	1.2	9.6

PCB threshold guidance levels: Level 1 values (µg kg^{-1}) derived from 95%ile of background values. Level 2 values from ERM. *No organic carbon results available for normalisation*

µg kg^{-1}	95%ile	AL1	AL 2/ERM
CB101	0.43	1.00	180
CB118	0.54	1.00	180
CB138	0.50	1.00	180
CB153	0.46	1.00	180
CB180	0.31	1.00	180
CB28	0.51	1.00	180
CB52	0.32	1.00	180
Σ7 ICES	3.23	7.00	1260

OCP action levels: valµes derived from 95%ile of background values.
No organic carbon results available for normalisation

µg kg^{-1}	95%ile	AL1	AL 2/ERM
HCB	0.18	0.27	230
γ - HCH	0.14	0.21	1

PAH guidance levels derived from 95%ile of background values, from MI data, 2001 - 2003. Values not normalised for organic carbon

PAH ug kg-1	**95%ile of Irish data**	**ERL**	**ERM**	**TEL**	**PEL**
Anthracene	116	85	1100	47	245
Acenaphthylene	34	44	640	6	128
Fluoranthene	524	600	5100		1494
Phenanthrene	397	240	1500		544
Pyrene	459	665	2600		1398
Benz-[A]-anthracene	265	261	1600	75	693
Benzo-[A]-pyrene	250	430	1600	89	763
Benzo-[ghi]-perylene	225			720 (AET- L)	2600 (AET - H)
Acenaphthene	54	16	500	7	89
Chrysene	336	384	2800	108	846
Dibenzo (ah) anthracene	63	63	260	6	135
Benzo(k) fluoranthene	234	280 (AET - L)	1620 (AET - H)		
Benzo(b) fluoranthene	331	320	1881		
Naphthalene	93	160	2100	35	391
Fluorene	129	19	540	21	144
Indeno-[1,2,3-cd]-pyrene	249	690	2600		
Total (sum 16)	3759	4257	26441	1113	9470

Annex 5: Comparison of existing ports data with proposed sediment quality guidance figures. Existing ports data provided by Enterprise Ireland Shannon Laboratory

Parameter	Units (dry weight)	Proposed lower level	Proposed upper level[1]	% of existing Port Data exceeding proposed upper level.	% of existing Port Data exceeding provisional action level 2
Arsenic	mg kg^{-1}	9[2]	70	2.3	0.5
Cadmium	mg kg^{-1}	0.7	4.2	3.7	5.4
Chromium	mg kg^{-1}	120	370	0.2	0
Copper	mg kg^{-1}	40	110[3]	2.4	3.7
Lead	mg kg^{-1}	60	220	4.4	2.8
Mercury	mg kg^{-1}	0.2	0.7	4.3	8.7
Nickel	mg kg^{-1}	21[2]	60	1.6	0
Zinc	mg kg^{-1}	160	410	7.7	3.1
Σ TBT & DBT	mg kg^{-1}	0.1	0.5	17*	16.1
γ – HCH (Lindane)	µg kg^{-1}	0.3	1	11.3	No provisional action level 2
HCB	µg kg^{-1}	0.3	1[3]	0	No provisional action level 2
PCB (individual congeners of ICES 7)	µg kg^{-1}	1	180		No provisional action level 2
PCB (Σ ICES 7)	µg kg^{-1}	7	1260	0	2
PAH (Σ 16)	µg kg^{-1}	4000			No provisional action level 2

[1] ERM (rounded up)

[2] ERL (rounded up) – No background Irish data available

[3] PEL used as ERM considered high

* TBT contamination generally occurs as a result of point source episodes, thus triggering further testing for delineation of problem area, and hence high level of failures seen above.

Annex 6: Review of existing international criteria

Europe

UK:
Current action levels in the UK (due to be revised imminently) were derived from concentrations of contaminants in dredged material, ie. purely from sediment chemistry. Biological effects were not included in the process (Read, pers comm.).

Revised (proposed) levels have been derived from background concentrations of estuarine sediments and historic datasets, taking into account ecotoxicologically derived levels from elsewhere (OSPAR, 2003). The revised (proposed) guidelines will be based on two action levels for metals, TBT and PCBs, and on one action level for PAHs. The lower threshold level values largely coincide with the corresponding ERLs, while the upper threshold values are fairly consistent with the corresponding ERMs.

The Netherlands:
The Dutch Uniform Content Test (UCT) was replaced in 2003 by a new *Chemical Toxicity Test* (CTT). The CTT is based on a revised list of parameters currently of more environmental concern including, for example, TBT. A requirement to quantify contaminants seldom encountered nowadays, including many of the OCPs, has been eliminated.

The CTT also includes a range of toxicity tests as standard prerequisite. Following close examination and inter-laboratory comparisons, four bioassay tests were selected for use on the contaminated sediments. These are: the 10 day whole sediment *Corophium* survival test; the 14 day whole sediment *Echinocardium* survival and reburial test; the Microtox Solid Phase test using Vibrio; and the DR Calux assay for dioxin-like activity.

For PCBs and PAHs, levels are set for sum of congeners only (PCBs), and sum of compounds only (PAHs), with the view that they afford a better measure of pollution by assessing combined activity or total sediment burden.

The CTT also removes the need for normalisation, believing the degree of biological availability of the contaminant is better-assessed using bioassays. Contaminant levels set for the CTT reflect levels employed by the UCT, except in “sum of” reckoning. This is despite no longer taking standardisation into account.

Although levels were originally set for ecotoxicology test, these are now used as guidance figures to establish the requirement for further analysis.

Action levels for the Netherlands are based on a standard sediment with 25% clay and 10% organic matter.

France:
The system in place in France has action levels for metals derived from natural background data (OSPAR, 2003). In the case of metals, twice the median background value was taken as Action Level 1, while four times the median value was taken for Action Level 2. The 95 percentile of background data is considered to be the geological background value.

For PCBs, figures were derived on the basis of human health requirements for consumption of fish living at the disposal sites. Action Level 1 was defined as half of the Level 2 figure, for consistency with the metals figures.

North America

Sediment quality in North America is assessed by way of ecotoxicological datasets, compiled by statistically matching laboratory chemical and bioassay data.

The effects range-median (ERM) and effects range-low (ERL) values are sediment quality guidelines based on a biological effects empirical approach. The values represent chemical concentration ranges that are rarely (i.e. below the ERL), sometimes (i.e. between ERL and ERM), and usually (i.e. above the ERM) associated with toxicity for marine and estuarine sediments. These values were derived, by Long *et al*. (1995), using only chemical concentration data associated with adverse effects.

Probable effects levels (PEL) and threshold effects levels (TEL), (Macdonald *et al.*, 1996), are sediment quality guidelines based on a biological effects empirical approach similar to ERMs/ERLs, but also using no-effects chemical concentration data. The lower of the two guidelines for each chemical (i.e. the TEL) is assumed to represent the concentration below which toxic effects rarely occur. In the range of concentrations between the two guidelines, effects occasionally occur. Toxic effects usually or frequently occur at concentrations above the upper guideline value (i.e. the PEL). Ranges are defined by specific percentiles of both the distribution of contaminant concentrations associated with adverse biological effects and the "no effects" distribution.

Apparent Effects Thresholds (AETs) are sediment chemistry screening values based on a biological effects correlation approach (USEPA, 1991). The AET is the highest concentration at which statistically significant differences in observed adverse biological effects from reference conditions do not occur, provided that the concentration also is associated with observance of a statistically significant difference in adverse biological effects. These values were derived from empirical data from toxicity tests on sediments from Puget Sound, using four types of organism (amphipods, oyster larvae, bacteria and in-situ biological effects measured by benthic infauna abundance). The USEPA defined the AET-low as the lowest AET among applicable biological indicators, and the AET-high as the highest AET among applicable biological indicators. AET derived levels tend to be the most liberal of the biological effects based SQGs.

Australia

Australia uses a four phased approach for assessment of dredged sediments, as follows:

- Evaluation of existing information
- Sampling and analysis of dredge spoil
- Bioavailablility and acute toxicity testing
- Sub-acute / chronic toxicity testing

Sediment quality action levels are largely based on the US biological effects based levels (ERLs & ERMs), with some modifications for local conditions. In determining disposal, contamination levels of dredge spoil are compared with background concentrations of sediment in the vicinity of the disposal site.

Table 6.1 summarises the upper end of the current action levels for several OSPAR Contracting Parties and also includes, for comparison purposes, class 3 of the Irish action levels. It is apparent that the action levels set for Irish dredged material compare fairly well with those of the rest of Europe for trace metals. These values are shown with the corresponding US effect-based method, which is widely felt to be the simplest operating system with the most validation[15].

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[15] ICES Working Group on Marine Sediments in relation to pollution, CW1.1, 2002.

Table 6.1. Sediment quality criteria – National and EU action levels and limit values for dredged material to be disposed at sea (from OSPAR, 2003). Also shows US Probable Effects Levels, as most conservative of biological indices.

	Ireland[1]	Norway	UK[2]	Belgium	Netherlands	France	US
mg kg^{-1} dw	Class 3	Category 2	Action level 2	Action level 2	Action level 2	Action level 2	PEL
	Heavily contaminated	Poor / bad	(cut off)				
Cadmium	>4.2	1-10	5	7	4	2.4	4.21
Chromium	>370.0	300 - 5000	400	220	120	180	270 (AET)
Copper	>110.0	150 - 1500	400	100	60	90	108
Nickel	>60.0	130 1500	200	280	45	74	42.8
Lead	>218.0	120 - 1500	500	350	110	200	112
Zinc	>410.0	700 - 10000	800	500	365	552	271
Mercury	>0.7	0.6 – 5	3.0	1.5	1.2	0.8	0.696
Arsenic	>70	80 - 1000	50-100	100	29	50	41.6
TBT & DBT	>0.5		1 [3]	7 µg Sn kg^{-1}	0.24		
PCB	>0.18		n/a [4]			Varies for individual congener	189
PCB total	>1.26	25 - 300 µg kg^{-1} [5]	0.2	2 µg goc^{-1} [6]	0.10 [7]	0.4	
PAH compounds		50-500 µg kg^{-1} [8]			0.8[9]		Varies for individual compound
Sum PAH		2000 - 20000 µg kg^{-1}		180 µg goc-1	8 [10]	45	
TPH				36 mg goc^{-1}[11]	1250 [12]		
HCB	1	2.5 – 50 µg kg^{-1}			20		230 (AET)

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[1] .Irish Action Levels

[2] Current values at time of writing. Proposed revised values awaiting approval (see Annex X)

[3] Sum of TBT, DBT, MBT

[4] Further congeners required if sum ICES 7 greater than action level 1 of 0.01µg g^{-1}.

[5] Probably sum 10

[6] Individual congeners

[7] Sum ICES 7 PCBs

[8] B(a)P

[9] Individual compounds except Fluoranthene which is 2.0 mg kg^{-1}

[10] Sum of 10

[11] Mineral oil

Annex 7: Background data used in the derivation of guidance level figures

Comparison of some ERLs (from Long, 1995) with (A) background levels of contaminants in Irish sediments (B) levels of contaminants in sediments from all Irish ports and harbours, and (C) background levels of contaminants in sediments from Irish ports and harbours.

		Background[1]	All ports data	All ports background[2]		
		(A) 95 %ile	(B) 95%ile	(C) 95%ile	ERL	ERM
Organic matter	%		8.46	8.90		
Hydrocarbons			635.80	878.60		
Solids			80.32	80.72		
Moisture			70.62	70.62		
Particle size distribution	% < 63 µm	98.56	88.67	89.46		
Copper	mg kg^{-1}	33.8	89.45	80.84	34	270
Zinc	mg kg^{-1}	154.8	562.60	278.20	150	410
Cadmium	mg kg^{-1}	0.71	3.47	0.97	1.2	9.6
Mercury	mg kg^{-1}	0.12	0.65	0.37	0.15	0.71
Tin	mg kg^{-1}		19.00	17.36		
Lead	mg kg^{-1}	53.8	248.80	73.33	46.7	218
Arsenic	mg kg^{-1}		37.90	38.90	8.2	70
Chromium	mg kg^{-1}	117.5	88.00	96.00	81	370
Manganese	mg kg^{-1}		808.58	842.50		
Nickel	mg kg^{-1}		49.00	47.00	20.9	51.6
Dibutyl tin	mg kg^{-1}		0.24	0.24		
Tributyl tin	mg kg^{-1}		2.39	0.88		
HCH Gamma	µg kg^{-1}	0.14	3.61	4.00		
DDD pp	µg kg^{-1}	0.45	20.95	26.50	2.2	27
DDE op	µg kg^{-1}	0.17			1.6	27
DDE (pp')	µg kg^{-1}	0.47	8.71	1.36	2.2	27
DDT (pp')	µg kg^{-1}	0.83	0.53	nd	1.6	27
Σ DDT	µg kg^{-1}	1.31			1.6	46.1
Hexachlorobenzene	µg kg^{-1}	0.18	0.05	0.06		
Anthracene	µg kg^{-1}		78.78	57.82	85.3	1100
Fluoranthene	µg kg^{-1}		373.85	306.60	600	5100
Phenanthrene	µg kg^{-1}		296.40	289.80	240	1500
Pyrene	µg kg^{-1}		308.55	289.35	665	2600
Benz-[A]-anthracene	µg kg^{-1}		198.75	168.40	261	1600
Benzo-[A]-pyrene	µg kg^{-1}		182.55	163.80	430	1600
Benzo-[ghi]-perylene	µg kg^{-1}		150.05	119.20	720[17]	2600[17]
Acenaphthene	µg kg^{-1}		16.02	11.26	16	500
Chrysene	µg kg^{-1}		236.60	203.60	384	2800
Dibenzo (ah) anthracene	µg kg^{-1}		53.35	nd		
Benzo(k) fluoranthene	µg kg^{-1}		183.60	64.08	280	1620
Benzo(b) fluoranthene	µg kg^{-1}		138.65	29.30	320	1880
Naphthalene	µg kg^{-1}		284.30	189.40	160	2100
Fluorene	µg kg^{-1}		22.55	22.00	19	540

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[17] Apparent effects threshold – low / high

		Background	All ports data	All ports background		
		(A) 95 %ile	(B) 95%ile	(C) 95%ile	ERL	ERM
Indeno-[1,2,3-cd]-pyrene	µg kg^{-1}		145.85	138.20	690[3]	2600[3]
PCB 028	µg kg^{-1}	0.51	16.50	5.07	22.7	180
PCB 052	µg kg^{-1}	0.32	30.47	28.66	22.7	180
PCB 101	µg kg^{-1}	0.43	33.50	38.22	22.7	180
PCB 138	µg kg^{-1}	0.50	45.17	40.62	22.7	180
PCB 153	µg kg^{-1}	0.46	44.35	35.90	22.7	180
PCB 180	µg kg^{-1}	0.31	20.59	15.10	22.7	180
PCB 118	µg kg^{-1}	0.54	32.22	34.71	22.7	180
sum 7	µg kg^{-1}	2.69				
TNONC	µg kg^{-1}	0.09				
CCdan	µg kg^{-1}	0.07				
TCdan	µg kg^{-1}	0.07				
Σ DDT	µg kg^{-1}	1.31				
DDE op	µg kg^{-1}	0.17				
DDD pp	µg kg^{-1}	0.45				

(a) analysed by Marine Institute laboratory

[2] (b) and (c) analysed by Enterprise Ireland laboratory, Environment Agency Nth Wales laboratory and CEFAS Burnham laboratory.

[3] Apparent effects threshold – low / high

Annex 8: Example of sampling and analysis plan for dredging projects.

A recommended sampling plan is detailed below. Please take the samples as close as possible to the positions listed below. Please supply your analysing laboratory with a copy of these details and ensure that the quality assurance requirements are met. Your attention is drawn particularly to conditions 4, 5, 6 & 7.

Sample No.	Easting	Northing	Parameters for analysis
1	79348	53475	1, 2, 3a, 3b, 3c, 3d, 3f, 3g, 3h
2	79430	53415	1, 2, 3a, 3b, 3c, 3e, 3f
3	79495	53393	1, 2, 3a, 3b, 3c, 3d, 3f, 3g
4	79422	55430	1, 2, 3a, 3b, 3c, 3e, 3f,
5	79365	56033	1, 2, 3a, 3b, 3c, 3d, 3f , 3g, 3h
6	79290	56643	1, 2, 3a, 3b, 3c, 3e, 3f
8	79149	55658	1, 2, 3a, 3b, 3c, 3e, 3f, 3h

In the event of chemistry results indicating any problems, toxicity tests <u>will</u> be required. You may wish to allow for this in taking additional sample (at least 1kg) at the time of original sampling. If this is the case, please ensure that this sample is refrigerated and stored in the dark, in a sealed container.

Parameter Code

1. Water content, density (taking into account sample collection and handling)
2. Granulometry including % gravel (> 2mm fraction), % sand (< 2mm fraction) and % silt (< 63µm fraction).
3. The following determinants in the sand-mud (< 2mm) fraction * :
    a) Total organic carbon
    b) Carbonate
    c) Mercury, arsenic, cadmium, copper, lead, zinc, chromium, nickel, iron, manganese.
    d) Organochlorines including γ-HCH (Lindane), and PCBs (to be reported as the 7 individual CB congeners: 28, 52, 101, 118, 138, 153, 180).
    e) Total extractable hydrocarbons.
    f) Tributyltin (TBT) and dibutyltin (DBT)
    g) Polycyclic aromatic hydrocarbons (PAH) - Anthracene, Fluoranthene, Phenanthrene, Benz-[A]-anthracene, Benzo-[A]-pyrene, Benzo-[ghi]-perylene, Chrysene, Benzo(k) fluoranthene, Naphthalene, Indeno-[1,2,3-cd]-pyrene, Benzo-(B)-fluoranthene, Pyrene
    h) Toxicity tests (Microtox or whole sediment bioassay) using appropriate representative aquatic species. (This requirement will depend on the results of the chemical analyses.)

**where the gravel fraction (> 2mm) constitutes a significant part of the total sediment, this should be taken into account in the calculation of the concentrations.*

4. It is advisable to collect sufficient samples to allow toxicity testing be carried out on the material. This may be required and will depend on the results of the above analyses.
5. Brief details of the methodologies used must be furnished with the results. This should include sampling, sub sampling and analytical methods used for each determinant
6. Appropriate marine CRM are to be analysed during each batch of analyses and the results to be reported along with sample results.

7. The required detection limits for the various determinants are given below.

Contaminant	Concentration	Units (dry wt)
Mercury	0.05	mg kg^{-1}
Arsenic	1.0	mg kg^{-1}
Cadmium	0.1	mg kg^{-1}
Copper	5.0	mg kg^{-1}
Lead	5.0	mg kg^{-1}
Zinc	10	mg kg^{-1}
Chromium	5.0	mg kg^{-1}
Nickel	15	mg kg^{-1}
Total extractable hydrocarbons	10.0	mg kg^{-1}
TBT and DBT (not organotin)	0.01	mg kg^{-1}
CB28	0.5	µg kg^{-1}
CB52	0.5	µg kg^{-1}
CB101	0.5	µg kg^{-1}
CB118	0.5	µg kg^{-1}
CB138+163	0.5	µg kg^{-1}
CB153	0.5	µg kg^{-1}
CB180	0.5	µg kg^{-1}
HCB	0.5	µg kg^{-1}
OCPs	0.5	µg kg^{-1}
Acenaphthene	20	µg kg^{-1}
Anthracene	20	µg kg^{-1}
Benzo (a) anthracene	20	µg kg^{-1}
Benzo (a) pyrene	20	µg kg^{-1}
Benzo (b) fluoranthene	20	µg kg^{-1}
Benzo (ghi) perylene	20	µg kg^{-1}
Benzo (k) fluoranthene	20	µg kg^{-1}
Chrysene	20	µg kg^{-1}
Fluoranthene	20	µg kg^{-1}
Indeno (1,2,3 – cd) pyrene	20	µg kg^{-1}
Naphthalene	20	µg kg^{-1}
Phenanthrene	20	µg kg^{-1}
Pyrene	20	µg kg^{-1}

Reports should include the following information:

- Date of sampling
- Treatment of samples and indication of sub sampling, compositing etc.
- Tabulated geophysical and chemical test results
- Summary method details
- Method performance specifications: Limit of detection, Precision, Bias
- Clear expression of units and indication of wet weight or dry weight basis
- Blanks & in-house references to be run with each sample batch, and reported with sample results.
- Appropriate Certified Reference Materials (CRM) to be run with each sample batch, and reported in full with sample results.
- If determinant is not detected, report less than values, and indicate LoD/ LoQ used.
- Other quality assurance information (e.g. accreditation status)

Annex 9: List of OSPAR JAMP relevant guidelines

Title	Date adopted	Dates revised	Comments[1]
JAMP guidelines for monitoring contaminants in biota	ASMO 1997		Status - Category I
Technical Annex 1 – determination of organic contaminants	ASMO 1997		Status - Category I
Technical Annex 2 – determination of metals	ASMO 1997		Status - Category I
Technical Annex 3 – determination of PAHs	ASMO(1) 1999		Status - Category I
JAMP guidelines for monitoring contaminants in sediments	ASMO 1997		Status - Category I
Technical Annex 1 – statistical aspects	ASMO 1997		
Technical Annex 2 – determination of CBs	ASMO 1997		Status - Category I
Technical Annex 3 – determination of PAHs	ASMO 1998		Status - Category I
Technical Annex 4 – determination of TBT	ASMO(1) 1999		Status - Category I
Technical Annex 5 – normalisation of contaminant concentrations	ASMO 2002		Status - Category I
Technical Annex 6 – Determination of metals – analytical methods	ASMO 2002		Status - Category I
JAMP guidelines on Quality Assurance for biological monitoring in the OSPAR area	ASMO 2002		
JAMP guidelines for general biological effects monitoring	ASMO 1997		Status - Category II
Technical Annex 1 – whole sediment bioassays	ASMO 1997		Status - Category II
Technical Annex 2 – sediment pore-water bioassays	ASMO 1997		Status - Category II
Technical Annex 3 – sediment sea water elutriates	ASMO 1997		Status - Category II
Technical Annex 4 – water bioassays	ASMO 1997		Status - Category II
Technical Annex 5 – CYP1a	ASMO 1997		Status - Category II
Technical Annex 6 – lysosomal stability	ASMO 1997		Status - Category II
Technical Annex 7 – liver neoplasia / hyperplasia	ASMO 1997		Status - Category I
Technical Annex 8 – liver nodules	ASMO 1997		Status - Category I
Technical Annex 9 – externally visible fish diseases	ASMO 1997		Status - Category I
Technical Annex 10 – reproductive success in fish	ASMO 1997		Status - Category II
JAMP guidelines for contaminant-specific biological effects monitoring	ASMO 1997		Status - Category II
Technical Annex 1 – metal-specific biological effects monitoring	ASMO 1997		Status - Category II
Technical Annex 2 – PAH-specific biological effects monitoring	ASMO 1997		Status - Category II
Technical Annex 3 – TBT-specific biological effects monitoring	ASMO 1997	ASMO 98 ASMO 02 ASMO 03	Status - Category I

1. Category I guidelines are those for which quality assurance procedures are in place. Category I guidelines may be used for monitoring and the data obtained are appropriate for Convention-wide assessments. Category II guidelines are those for which quality assurance procedures are not yet in place. Category II guidelines may be used for monitoring although caution should be exercised when making comparisons of the data obtained between different Contracting Parties

Annex 10: Questionnaire for laboratory approval for chemical analyses of dredged material

Please fill in separate forms for each of the following parameters –

- Trace metals
- Organochlorine pesticides / PCBs
- PAHs
- TBT / DBT / MBT

Guideline for completion of questionnaire:

- Approval will be on the basis of parameters tested.
- If analysis are subcontracted for any tests the subcontractor should also complete this questionnaire for approval
- Should there be a significant change in methodology used, please complete this questionnaire again for the relevant test and re-submit.
- Required information may be given as separate attachments

Category of analyses (e.g. metals, organics..)	
Which specific parameters does your laboratory analyse for?	
What experience do you have in analysing these parameters in aquatic sediments (e.g. years analysing, frequency of marine samples)?	
Please supply brief description of methodology, including extraction, clean-up and detection methods.	
Are the methods validated?	
Please list performance characteristics. (Ensure units are clear – e.g. precision as CV and please explain the basis of precision)	LoD: Accuracy: Precision:
Does your laboratory participate in	

appropriate marine sediment proficiency testing schemes? If so, which and since when?	
Is your laboratory accredited for such tests? If so, in accordance with which system?	
If the answer to the above is no, do you run an in-house quality system? If so, please give details.	
Do you regularly run appropriate marine CRMs? Please state which ones.	
Do you run in-house references with each batch of analysis?	
Do you maintain control charts for analyses of all reference materials?	
What system is in place for identifying and addressing non-conformances?	
Comments:	

Please revert to Margot Cronin at the Irish Marine Institute with any queries. (+353 (0)91 387200 or margot.cronin@marine.ie)

Annex 11 Standard format for reporting sediment chemistry results *(Excel spreadsheet template will be provided by Marine Institute)*

Location:	Laboratory											
	Sub-contract											
	Sample		LoD	CRM (meas)	CRM (certified)	In-house ref	Blank (y/n)	1	2	3	4	5
	Visual appearance, any signs of life eg worms?											
Date of sampling:	Position (dd/mm.ss)	lat										
		long										
	units											
	H_2O	%										
	<2mm	%										
CRMs used:	<63um	%										
	OC	%										
	TEH											
	Cu											
	Zn											
	Cd											
Fraction analysed:	Hg											
	Pb											
	As											
	Cr											
	Mn											
	Ni											
	Li											
	Al											
Are results reported as wet weight or dry wt?	DBT											
	TBT											
	Σ TBT + DBT											

Location:	Sample		LoD	CRM (meas)	CRM (certified)	In-house ref	Blank (y/n)	1	2	3	4	5
	PCB 028											
	PCB 052											
	PCB 101											
	PCB 138											
	PCB 153											
Date of sampling:	PCB 180											
	PCB 118											
	Σ 7 PCB											
	Acenaphthene											
	Acenaphthylene											
CRMs used:	Anthracene											
	Benzo (a) anthracene											
	Benzo (a) pyrene											
	Benzo (b) fluoranthene											
	Benzo (ghi) perylene											
Fraction analysed:	Benzo (k) fluoranthene											
	Chrysene											
	Dibenz (a,h) anthracene											
	Flourene											
	Fluoranthene											
Are results reported as wet weight or dry wt?	Indeno (1,2,3 – cd) pyrene											
	Naphthalene											
	Phenanthrene											
	Pyrene											
	Σ 13 PAH											
	HCH Gamma											
	HCB											
Notes / comments:												