ICMM
International Council on Mining & Metals

Hazard assessment of ores and concentrates for marine transport

Materials Stewardship
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Contents

This publication describes the scientific progress made since the 2009 release of *Ores and concentrates: an industry approach to EU hazard classification.*

Foreword

Ensuring that our materials are not only produced, but also handled and used safely and in a way that improves human and ecosystem well-being over the long term is an important part of every mining and metals company's responsibility. It is a vital part of ensuring an overall positive contribution of mining and metals to sustainable development.

The first step in the life cycle of metals is the extraction and processing of mineral ores to create concentrates. They then go on to be refined to the metals and minerals that are used by society.

Accurate hazard assessment of concentrates – this starting point – is essential for ensuring that any potential environmental and health risks associated with their production, transport and storage are properly managed. This is part of the industry's commitment to sustainable development and is essential for building society's trust and for ensuring an ongoing social licence to operate.

In regulation, this responsibility was first enshrined in the United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS). More recently, the amendment of several transport codes by the International Maritime Organization (IMO) took place. The IMO initiative covered all potentially hazardous substances – including ores and concentrates – and put greater emphasis on understanding the potential risks to ship crews and the marine environment.

ICMM and others in the mining and metals industry have invested significantly in developing scientifically robust and consistent approaches to classification of materials including ores and concentrates over the last decade. This work has positioned the industry well. Practical implementation however has led to some significant challenges: (1) there are many producers of ores and concentrates around the world; (2) there are huge variations in types of ores and concentrates that are shipped. This makes understanding of the techniques required for accurate hazard assessment of paramount importance.

In this guidance ICMM sets out the approach that leading mining and metals commodity associations have developed in collaboration with scientific experts from research institutes around the world. It is an approach based on the latest scientific principles and one that accounts for the differences in data availability and testing facilities that may be experienced by companies around the world.

The assessment of cargoes is, in the end, the responsibility of the company that ships them. However, through this guidance we hope to promote a consistent and responsible approach for assessment of materials governed within the IMO mandate and generated by the mining and metals industry. This is a key part of ensuring that mining and metals generates the positive contribution to sustainable development that it seeks to do.

R Anthony Hodge
President, ICMM

Introduction

Recently, new amendments to existing international regulations with regard to the marine transport of materials in packaged and in solid bulk form have been introduced by the International Maritime Organization (IMO). These aim to ensure safe shipment of cargoes and the protection of the marine environment from harmful pollutants.

These regulations include the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex V, the International Maritime Solid Bulk Cargoes (IMSBC) Code and the International Maritime Dangerous Goods (IMDG) Code.
The new provisions that have been introduced are intended to control risks and the measures that must be taken by shippers depend on the physical, human health and environmental hazards of the material transported. Assessment of these hazards is based on the UN Globally Harmonized System of Classification and Labelling of Chemicals (GHS).

This document has been written with the specific case of ores and ore concentrates (hereafter termed O&Cs) in mind. These products of mining are solid materials that are often transported by sea, usually in bulk, but sometimes in packaged form. While the guidance here is focused on O&Cs, it could be applied to any other inorganic complex solid materials transported in bulk or packaged form.

The hazards of O&Cs must be assessed to determine whether compliance with special requirements defined in the MARPOL Convention, IMSBC Code or IMDG Code is needed.

The aim of this document is to provide an overview of:

- the GHS system and the various IMO regulations that link it to marine transport of O&Cs
- the specific hazards considered in each of the marine regulations
- the science-based hazard assessment strategy developed by the international mining and metals industry for applying the GHS to O&Cs.

This document provides general guidance for mining and metals industry personnel on the hazard classification requirements for marine transport of O&Cs. It is intended as general classification guidance and is not a substitute for expert advice. The document does not cover the evaluation of Transportable Moisture Limits (to assess bulk materials that may liquefy).

This document also does not cover the consequences of hazard classification under marine transport legislation.

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More than 90 per cent of global trade is carried by sea.

Principles of hazard classification

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1 Principles of hazard classification

The terms "hazard" and "risk" are fundamentally different. The hazard of a substance or mixture represents its inherent properties and potential effect on the environment, human health or property. On the other hand, the risk of a substance or mixture represents the likelihood and extent to which a person, the environment or property may be harmed or otherwise adversely affected when exposed to it.

1.1 The objectives of hazard classification

The hazard assessment and classification of a substance or mixture involves the evaluation of intrinsic characteristics that may have a detrimental/harmful effect on a set of environmental, human health and physical endpoints. The GHS provides a standard set of end points, effect levels and agreed test procedures. These have been adopted as the basis for the various IMO regulations as described below.

Depending on the concentration, or dose, at which the substance causes a specific adverse effect, it will be categorized in a specific classification group, with "Category 1" representing the most stringent hazard classification (highest potential hazard) and "Not classified" (no effects found at the highest tested concentration) as the least stringent classification. This is done for each end point. This classification system allows more hazardous chemicals to be distinguished from those that are less hazardous.

1.2 Global harmonization – the GHS

In an attempt to standardize the many hazard classification and labeling systems that have been in use in different countries since the 1980s, the United Nations (UN) designed the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). The aim of the GHS is to facilitate international trade by increasing consistency (or harmonization) of regulation among countries that have different hazard assessment criteria and communication requirements. The GHS was first published in 2003 and is updated every two years. The current versions of the IMO regulations are based on the 4th Revision (2011) and that is reflected in this guidance.

All versions of GHS are available at: **http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html.**

The UN is encouraging broad international adoption of the GHS and currently more than 60 countries or regions have implemented it, including Australia, Brazil, China, Europe, Japan, South Korea and the United States.

Table 1: **GHS hazard classes**

	HAZARD CLASSES
Physical	Explosives
	Flammable gases/aerosols/liquid/solids
	Oxidizing gases/liquids/solids
	Gases under pressure
	Self-reactive substances and mixtures
	Pyrophoric liquid/solid
	Self-heating substances and mixtures
	Substances and mixtures which on contact with water emit flammable gases
	Organic peroxides
	Corrosive to metal
Human health	Acute toxicity (via the oral, dermal, inhalation route)
	Skin corrosion/irritation
	Serious eye damage/eye irritation
	Respiratory/skin sensitization
	Germ cell mutagenicity
	Carcinogenicity
	Reproductive toxicity
	Specific target organ toxicity (STOT) – single exposure
	Specific target organ toxicity (STOT) – repeated exposure
	Aspiration hazard
Environmental	Hazardous to the aquatic environment
	Hazardous to the ozone layer

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Currently more than 60 countries or regions have implemented GHS including Australia, Brazil, China, Europe, Japan, Korea and the United States.

The GHS applies to both substances and mixtures. Substances are defined in the GHS as: "Chemical elements and their compounds in the natural state or obtained by any production process, including any additive necessary to preserve the stability of the product and any impurities deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition". Mixtures are defined in the GHS as: "a mixture or a solution composed of two or more substances in which they do not react".

The GHS covers three types of hazard: physical, human health and environment. The end points, or hazard classes, considered for each are shown in table 1.

1 Principles of hazard classification

There is no testing requirement under the GHS; hazard classification is based on available reliable data (including animal data, *in vitro* data and human epidemiological data) and in the absence of experimental evidence, expert judgement. Data should be obtained following internationally accepted test guidelines (eg UN, OECD) and, where possible, in laboratories that are Good Laboratory Practice (GLP) compliant. The GHS provides extensive guidance on how to assess relevancy and reliability of data for hazard classification. This guidance is especially important for metals and their compounds. Careful evaluation of the quality and relevancy of data is critical to prevent inaccurate hazard classification.

The GHS applies to metals, metal compounds and complex metal-containing products. Specific guidance on the environmental hazard assessment of metals and metal compounds is provided in Annex 9.7 (Classification of metals and metal compounds) and Annex 10 (Guidance on transformation/dissolution of metals and metal compounds in aqueous media).

1.3 Basic approaches for the classification of substances and mixtures

Depending on the type of information available, there are several approaches to assessment of the hazard classification of a substance or mixture. These are generally based on:

- experimental (eco-)toxicological data that is generated with the substance or mixture
- the classification of a comparable substance or mixture using "read-across"[1] or "bridging" principles[2]
- a calculation method based on the hazards of the components.

These classification approaches and their applicability to O&Cs are explained further in Section 3 of this document.

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Annexes 9.7 and 10 of the GHS contain specific guidance for minerals and metals.

1 Read-across: extrapolation of known data from one substance to another substance based on the assumption that the two substances will cause similar biological responses.

2 Bridging principles: derivation of health or environmental classification of mixtures based on available data on similar tested mixtures and on the ingredient substances.

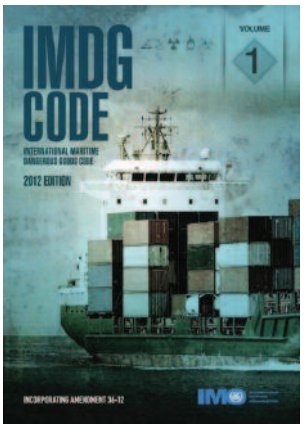
Hazard assessment for marine transport

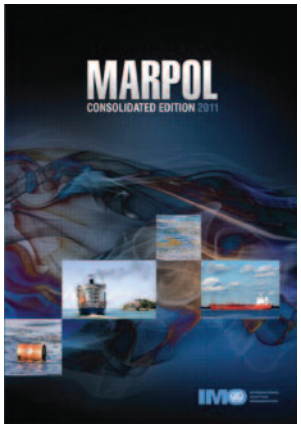
2 Hazard assessment for marine transport

Marine transport is controlled through various international regulations, each aiming to prevent or reduce the adverse impact on man, environment and property during transport and through accidental releases.

Each of these regulations includes special provisions for dangerous goods (ie materials with certain hazardous properties) and each builds upon the GHS for the hazard identification of the materials. The most relevant regulations for marine transport of solid materials are:

- International Maritime Dangerous Goods Code (IMDG Code)
- International Maritime Solid Bulk Cargoes Code (IMSBC Code)
- International Convention for the Prevention of Pollution from Ships (MARPOL)





2.1 IMDG Code for marine transport of packaged goods

The International Maritime Dangerous Goods (IMDG) Code (2012) was developed to ensure the safe maritime transport of packaged dangerous goods, including substances, mixtures and articles. The IMDG Code became mandatory on 1 January 2004 and is updated every second year. This code is built on the UN Model Regulations also known as the "orange book" (UN Recommendations on the Transport of Dangerous Goods – Model Regulations).

The IMDG Code can be obtained through the IMO website: **www.imo.org/Publications/Pages/Home.aspx.**

Provisions of the IMDG Code include requirements related to packaging, labels and placards, container traffic and stowage, segregation of incompatible goods and transport documents.

Substances, mixtures and articles with certain hazardous properties are called dangerous goods. Dangerous goods are materials that are listed in the IMDG Code's Dangerous Goods List and others that meet the criteria of specific GHS hazard classes and categories.

The IMDG Code's Dangerous Goods List is mandatory. Deviations from this list are possible in exceptional circumstances and conditional upon specific measures being followed.

Dangerous goods are classified in nine different classes corresponding to different hazard endpoints. In some cases, the classes have divisions that specify varieties of hazards within the class. Most hazards are identified following GHS principles and guidance. Safety and precautionary measures, such as packing requirements, are specified for each hazard type.

The nine classes and divisions are largely – but not entirely – based on the GHS system and are shown in Table 2.

For an overview of the health-, environment- and some of the physical related hazard end points, relevant to ores and concentrates, considered under the IMDG Code and how they relate to the GHS criteria, see Table 3.

Table 2: IMDG Code hazard classes

	HAZARD
Class 1	Explosives
Class 2	Gases
Class 3	Flammable liquids
Class 4	Flammable solids; substances liable to spontaneous combustion; substances which, in contact with water, emit flammable gases
Class 5	Oxidizing substances and organic peroxides
Class 6	Toxic and infectious substances
Class 7	Radioactive material
Class 8	Corrosive substances
Class 9[3]	Miscellaneous dangerous substances and articles.

2.2 IMSBC Code for marine transport of solid bulk cargoes

The aim of the International Maritime Solid Bulk Cargoes (IMSBC) Code (2012) is to ensure safe maritime transport of solid bulk materials. Since 2008, the IMSBC Code supersedes the Code of Safe Practice for Solid Bulk Cargoes (BC Code).

The IMSBC Code is updated every second year and the current version can be ordered through the IMO website: **www.imo.org/Publications/Pages/Home.aspx.**

The IMSBC Code specifies requirements related to the safe stowage and shipment of solid bulk cargoes that may give rise to relevant on-board risks, for example structural damage due to improper cargo distribution, loss or reduction of stability during a voyage, chemical reactions of cargoes such as spontaneous combustion, emission of toxic or explosive gases, corrosion, etc.

The IMSBC Code categorizes cargoes into three groups:

- Group A – cargoes that may liquefy
- Group B – cargoes possessing chemical hazards
- Group C – cargoes that are neither liable to liquefy nor possess chemical hazards.

Cargoes can be Group A, B or C or Group A and B. Group B cargoes are those that meet either the IMDG Code's "dangerous goods" hazard criteria or the IMSBC Code's "materials hazardous only in bulk" (MHB) criteria.

Specific criteria to identify MHB cargoes were introduced in the IMSBC Code in 2013 and include physical hazard, acute and chronic health-related end points. The introduction of chronic human health end points is a significant deviation from other transport legislation such as the IMDG Code where toxic substances (Class 6.1) are defined only by their acute health hazards.

MHB hazards include:

- combustible solids
- self-heating solids
- solids that evolve into flammable gas when wet
- solids that evolve toxic gas when wet
- toxic solids
- corrosive solids.

Both sets of Group B hazard criteria are largely based on GHS criteria. However, there are some differences related to the cut-off values for some of the MHB criteria. These need to be checked carefully when assessing the MHB properties of a cargo.

For an overview of the hazard end points relevant to ores and concentrates, considered under the IMSBC Code and how they relate to the GHS criteria, see Table 3.

The IMSBC Code contains a list of solid cargoes transported in bulk. Information on their hazards, handling measures, loading, unloading, carriage, stowage and segregation recommendations are given in cargo-specific "schedules". The IMSBC code specifies that these schedules are not exhaustive. It is the shipper's obligation to provide to the shipmaster all available information on the hazards of the cargo. Where a new hazard is identified for a solid bulk cargo, the existing schedule is updated or a new schedule created to be integrated in the IMSBC Code.

The current IMSBC Code includes a schedule for the shipment of *mineral concentrates*, categorized as Group A cargo, and a schedule for *metal sulphide concentrates* as a Group A and B cargo. These schedules can be applied for a wide range of metal ores and concentrates. The latter schedule has to be followed for cargoes that have any of the Group B hazards listed in the metal sulphide concentrate schedule.

3 This class includes environmentally hazardous substances (termed 'marine pollutants').

2 Hazard assessment for marine transport

2.3 MARPOL Annex V for marine transport of solid bulk cargoes

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. The MARPOL Convention was adopted in 1973, whereas the actual Protocol was adopted in 1978. The combined instrument – MARPOL 73/78 – entered into force in 1983, and has been updated by amendments through the years.

MARPOL 73/78 and its annexes can be ordered through the IMO website: **www.imo.org/Publications/Pages/Home.aspx.**

The Protocol includes six technical annexes:

- Annex I: Regulations for the prevention of pollution by oil
- Annex II: Regulations for the control of pollution by noxious liquid substances in bulk
- Annex III: Regulations for the prevention of pollution by harmful substances carried by sea in packaged form
- Annex IV: Regulations for the prevention of pollution by sewage from ships
- Annex V: Regulations for the prevention of pollution by garbage from ships
- Annex VI: Prevention of air pollution from ships

Consistent with the principles of the GHS, MARPOL Annex V is based on self-classification of cargoes by the shipper and inclusion of a relevant statement (ie HME or not HME) in the 'shippers declaration form'. A list-based system may in future become part of this process.

Substances harmful to the marine environment (HME)

Amendments to MARPOL Annex V of relevance to O&Cs were adopted in July 2011 (MARPOL Annex V, 2011), and came into force in January 2013. MARPOL Annex V Implementation guidelines were adopted in 2012. The newly adopted amendments prohibit the discharge of all garbage into the sea, unless explicitly permitted. Dry cargo residues and wash water containing such residues are defined as garbage and subject to the provisions of the Annex. Cargo residue not classified as harmful to the marine environment (HME) can be discharged to the sea, outside special areas. The amendments specify that residues and wash waters of HME cargoes shall be discharged at adequate port reception facilities.

The criteria to identify HME cargoes are based on the GHS[4] environmental and human health toxicity end points and include:

1. acute aquatic toxicity Category 1; and/or
2. chronic aquatic toxicity Category 1 or 2; and/or
3. carcinogenicity[5] Category 1A or 1B combined with not being rapidly degradable and having high bioaccumulation; and/or
4. mutagenicity[5] Category 1A or 1B combined with not being rapidly degradable and having high bioaccumulation; and/or
5. reproductive toxicity[5] Category 1A or 1B combined with not being rapidly degradable and having high bioaccumulation; and/or
6. specific target organ toxicity repeated exposure[5] Category 1 combined with not being rapidly degradable and having high bioaccumulation; and/or
7. solid bulk cargoes containing or consisting of synthetic polymers, rubber, plastics, or plastic feedstock pellets (this includes materials that are shredded, milled, chopped or macerated or similar materials).

Assessment of the environmental criteria (1, 2) and the plastic/rubber criteria (7) for solid bulk cargoes should have been made by 1 January 2013. Assessment of the human health related criteria (3-6) should be made by 1 January 2015. For an overview of the health- and environment-related hazard end points considered under MARPOL Annex V and how they relate to the GHS criteria, see Table 3.

4 The criteria are based on GHS, fourth revised edition (2011). For specific products (eg metals and inorganic metal compounds) guidance available in GHS, annexes 9 and 10 are essential for proper interpretation of the criteria and classification and should be followed.

5 Products that are classified for Carcinogenicity, Mutagenicity, Reproductive toxicity or Specific Target Organ Toxicity Repeated Exposure for oral and dermal hazards or without specification of the exposure route in the hazard statement.

Table 3: Overview of hazard end points and classification categories under the various systems relevant to ores and concentrates

HAZARD END POINT	UN GHS	MARPOL Annex V	IMDG[1] Code	IMSBC Code
Human health				
Acute – oral	Category 1	–	Class 6.1	Group B – Class 6.1
	Category 2	–	Class 6.1	Group B – Class 6.1
	Category 3	–	Class 6.1	Group B – Class 6.1
	Category 4	–	–	–
Acute – dermal	Category 1	–	Class 6.1	Group B – Class 6.1
	Category 2	–	Class 6.1	Group B – Class 6.1
	Category 3	–	Class 6.1	Group B – Class 6.1
	Category 4	–	–	Group B – MHB
Acute – inhalation	Category 1	–	Class 6.1	Group B-Class 6.1
	Category 2	–	Class 6.1	Group B-Class 6.1
	Category 3	–	Class 6.1	Group B-Class 6.1
	Category 4	–	–	Group B – MHB[3]
Skin corrosion/irritation	Category 1 (A, B, C)	–	Class 8	Group B – Class 8
	Category 2	–	–	Group B – MHB
Serious eye damage/irritation	Category 1	–	–	Group B – MHB
	Category 2A	–	–	Group B – MHB
Respiratory sensitization	Category 1 (A, B)	–	–	Group B – MHB
Mutagenicity	Category 1 (A&B)	HME[2]	–	Group B – MHB
	Category 2	–	–	–
Carcinogenicity	Category 1 (A&B)	HME[2]	–	Group B – MHB
	Category 2	–	–	–
Reproductive toxicity	Category 1 (A&B)	HME[2]	–	Group B – MHB
	Category 2	–	–	–
STOT – single exposure	Category 1	–	–	Group B – MHB[4]
	Category 2	–	–	–
	Category 3	–	–	–
STOT – repeated exposure	Category 1	HME[2]	–	Group B – MHB[4]
	Category 2	–	–	–

Table 3 continued on page 14

(1) The IMDG Code considers additional hazards. Only those end points relevant for O&C are listed in this table.

(2) Classification for oral and dermal routes or without specification of the exposure route in the hazard statement. Product is considered HME if it also meets the criterion of "high bioaccumulation" and is "not rapidly degradable".

(3) Effects due to cargo dust and/or effects due to toxic gases that are formed when the cargo is wet.

(4) Inhalation and dermal exposure routes.

– Hazard end point and/or category not considered under this legislation.

2 Hazard assessment for marine transport

Table 3: Overview of hazard end points and classification categories under the various systems relevant to ores and concentrates *continued*

HAZARD END POINT	UN GHS	MARPOL Annex V	IMDG[1] Code	IMSBC Code
Environment				
Aquatic acute	Category 1	HME	Class 9	–
	Category 2	–	–	–
	Category 3	–	–	–
Aquatic chronic	Category 1	HME	Class 9	–
	Category 2	HME	Class 9	–
	Category 3	–	–	–
	Category 4	–	–	–
Physical hazards				
Explosive solids	Div 1.1 to 1.6	–	Class 1 – Div 1.1 – 1.6	–
Oxidizing solid	Category 1	–	Class 5.1	–
	Category 2	–	Class 5.1	–
	Category 3	–	Class 5.1	–
Flammable solids – readily combustible	Category 1	–	Class 4.1	–
	Category 2	–	Class 4.1	–
	–	–	–	Group B – MHB[5]
Flammable solids – self-reactive	Type A to G	–	Class 4.1	–
Flammable solids – pyrophoric substances	–	–	Class 4.2	–
Flammable solids – self-heating	Category 1	–	Class 4.2	–
	Category 2	–	Class 4.2	–
	–	–	–	Group B – MHB[6]
Flammable solids – solids that evolve into flammable gas when wet	Category 1	–	Class 4.3	–
	Category 2	–	Class 4.3	–
	Category 3	–	Class 4.3	–
	–	–	–	Group B – MHB[7]
Corrosive to metals	Category 1	–	Class 8	–
	–	–	–	Group B – MHB[8]

(5) MHB classification cut-off value different than in the GHS (Group B – MHB if the time of burning is less than 2 minutes for a solid sample and less than 20 minutes for a metal powder; the GHS specifies classification if less than 45 seconds for solid sample and 10 minutes or less for a metal powder).

(6) MHB classification cut-off value different than in the GHS (Group B – MHB if the temperature rise over the oven temperature is more than 10°C; this is lower than the minimum temperature rise considered under the GHS, which is 60°C).

(7) MHB classification cut-off value different than in the GHS (Group B – MHB if the flammable gas evolution rate is greater than zero–rate calculated over 48 hours; this is lower than the minimum rate considered under the GHS of greater than 1L/kg – calculated over 7 hours).

(8) MHB classification cut-off value different than in the GHS (Group B – MHB if corrosion rate is between 4mm and 6.25mm/year; this is different to the limit of >6.25mm/year under the GHS).

– Hazard end point and/or category not considered under this legislation.

Hazard classification of ores and concentrates

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3 Hazard classification of ores and concentrates

Ores and concentrates are complex inorganic materials consisting of aggregates of natural minerals and their properties are influenced by their geological environment of formation. The mineral constituents they contain can be characterized by their chemical composition and crystal structure.

O&Cs are generally best described by the physical properties which relate to this chemical structure and composition. Common distinguishing characteristics include crystal structure and habit, hardness, specific gravity, particle size and solubility. The extent to which metal ions are released from these complex mineral structures determines to a large extent their human health and environmental hazard potential. Therefore, applying the GHS rules to O&Cs requires expert knowledge and the assessment of such potential for metal release.

While GHS provides extensive guidance on how to assess hazards and classify metals and metal compounds for the environment (Annex 9.7), and how to determine transformation/dissolution of metals and metal compounds in aqueous media (Annex 10), guidance on how to classify complex materials such as O&Cs is not provided. Such guidance is provided in The International Council on Mining and Metals (ICMM) and Euromines' guidance document *Ores and concentrates: an industry approach to EU hazard classification* (ICMM, 2009) and in the ICMM *Metals Environmental Risk Assessment Guidance (MERAG) factsheet on classification* (ICMM, 2014). Although the former is focused on the EU, the guidance is applicable in other jurisdictions.

As O&Cs have an inherently variable composition, each cargo must be assessed for its particular hazards. However, testing every product that is shipped in bulk is not practical and may not be desirable. Instead, a testing and assessment strategy based on GHS principles has been developed by the international mining and metals industry to assess the hazards of complex inorganic materials. This approach is described in the following sections. More detailed background, particularly on the underlying scientific principles, can be found in the previously referenced guidance document and factsheet published by ICMM.

The approach described in this section has been applied by several metal commodity associations to support their members' compliance with marine transport legislation. It includes:

1. characterization of the composition
2. hazard data collection and review
3. tiered classification based on data availability.

3.1 Characterization of the composition of ores and concentrates

O&Cs are naturally occurring complex materials with variable composition. Concentrates of the same metal but from different mines can differ in composition so their hazard classification will be different. Similarly, the composition of a concentrate from a particular mine will vary over time as it is extracted from different parts of the ore body, meaning that its classification might change over time.

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International Convention for the Prevention of Pollution from Ships is introduced by the IMO.

Accurate characterization of O&Cs is a requisite step for an accurate hazard classification and should include collection of data on its elemental and mineralogical composition. The more data that is available on the characteristics of a complex material, the more accurate the hazard assessment can be. For classifying cargoes with few data, conservative assumptions must be used.

A proper characterization of the composition of an O&C should take into account the following:

- A full elemental and mineralogical composition analysis should be determined.
- Particle size distribution information should be developed.
- The relevant constituents of an O&C are those which are present in a concentration equal to or greater than the generic cut-off values defined by GHS for each hazard end point. Where there is evidence that a component present at a concentration less than the generic cut-off can still be relevant for classifying an O&C it should also be included.
- Composition data should be collected from representative samples of the O&C as shipped.
- Composition data should be collected at different periods during the year. This data is then used to derive typical concentration ranges for each listed mineral and to identify any trends influencing the hazard classification. Historical analytical data can also assist in establishing typical concentration ranges.
- Geological information on the ore body can support the determination of the O&C composition and the interpretation of the results.

Table 4: Example of acute and chronic ecotoxicity reference values of metal ions commonly found in O&C

METAL ION	ACUTE ERV (µg/l)[6]	CHRONIC ERV (µg/l)[6]
As	430	40
Co	90	4.9
Cu	25	20
Ni	68	2.4
Pb	73.6	17.8
Zn	413	82

3.2 Collection of data for hazard classification

To assess the hazard classification of an O&C, all available information should be considered, including:

- The appropriate information on the composition as detailed in Section 3.1.
- The hazard classification information of similar O&Cs from which classification could be read-across.
- The hazard classification of constituent minerals; this includes both officially listed classifications (eg EU CLP (classification, labelling and packaging) and self-classifications made by industry. A good source of such information is the metals classification (Meclas) tool, which contains both the latest official classifications and industry data and is available online at **www.meclas.eu**.
- The concentration of the metal ion in solution, produced during transformation/dissolution (T/D) testing in a standard aqueous medium after 7 and 28 days, of the O&C, similar O&C and/or constituent minerals.
- Bioaccessibility data on the O&C, similar O&C and/or constituent minerals.
- The acute and/or chronic ecotoxicity reference values (ERV) of the metals in the O&Cs that are classified for the environment either as a metal or as components of certain inorganic compounds. For many metal ions, acute and chronic ERVs have been derived to comply with the EU-REACH (registration, evaluation, authorization and restriction of chemicals) and CLP regulations (EU's implementation of GHS). These have been produced following a thorough screening of available data for relevancy and quality. ERVs are mostly available for freshwater. As specified in GHS, freshwater and marine species toxicity data can be considered equivalent data. Where there is however evidence of different sensitivities, the results showing the highest toxicity should be chosen. An overview of the acute and chronic ERVs of several metals commonly found in O&Cs is given in Table 4. This table is not exhaustive and a full list of high-quality ERVs is embedded in the Meclas tool (see above). Their use is important to ensure consistency in hazard classification.
- Acute toxicity values (LD50, LC50) of constituent minerals classified for acute toxicity where available.

6 ERV at pH6.

3 Hazard classification of ores and concentrates

3.3 Tiered environmental classification approach

For most O&Cs, little or no acute or chronic ecotoxicity data of sufficient relevancy or quality for use in hazard assessment is available. Considering the inherent variability in composition of O&Cs testing every product that is shipped in bulk is not practical and may not be desirable (for reasons of animal welfare, cost and availability of test laboratory facilities). Instead, an intelligent tiered testing and assessment strategy is followed to assess the environmental hazards of O&Cs. The approach is presented in Figure 1 and summarized below. It allows the user to make an assessment based on the data available. This gives the option to develop further data and eliminate conservative assumptions to refine a classification if desired.

Classification using available transformation/dissolution data on O&C

Where 7-day and 28-day transformation/dissolution (T/D) data is available for the O&C, these are used to assess the aquatic hazard classification by comparing the solubility of each relevant metal ion with respectively their acute and chronic ERV and applying the GHS additivity or summation rule. Such assessment can be made using for example the Meclas tool.

Classification based on read-across from similar O&Cs

Where no T/D data is available for the O&C, but the composition is very similar (eg it fits within a range of previously tested representative samples) to a group of O&Cs for which T/D[7] and classification data is available, the O&C can be classified by reading across the classification from the similar group.

Classification based on data of constituent minerals

Where read-across is not possible from a group of similar O&Cs and no T/D data is available for a specific O&C under investigation, but T/D data is available for the minerals present in the specific O&C, the T/D data of the minerals[8] and the ERVs of the relevant metal ions is used to assess the aquatic hazard classification of the O&C. This can be done following the GHS additivity rule or the summation rule – in the latter case using the classification of the constituent minerals derived using the mineral T/D data and ERVs of the relevant metal ions in the minerals. Such assessment can again be made using the Meclas tool.

Classification – worst case approach in absence of data

If no T/D data are available for the O&C or the constituent minerals, and read-across from a similar group of O&Cs is not possible, a worst case classification approach is applied, assuming all relevant metal ions present in an O&C are soluble and following the GHS additivity rule or the summation rule – using in the latter case the classification of soluble metal compounds.

Laboratory testing

In case of uncertainty in the outcome of the assessment, classifications can always be refined or validated by further T/D testing of O&Cs, of its constituent minerals and as a last resort through ecotoxicity tests on the O&C itself.

Following the above approach, under the IMDG code, O&Cs that meet the criteria acute aquatic toxicity Category 1 and or chronic aquatic toxicity Category 1 or 2 are classified as Class 9.

Under MARPOL Annex V, O&Cs that meet the criteria acute aquatic toxicity Category 1 or chronic aquatic toxicity Category 1 or 2 are classified as HME.

More details on the approach, research data and resulting classifications are available for various groups of ores and concentrates via the relevant metals commodity associations (see Section 5 for contact details). Some have also developed simple models, based on the approach described above, to predict the environmental classification of the O&Cs of their metal (eg Cu, Zn). Where these are available, the only information shippers need to make the required assessment is the elemental and mineralogical composition of their O&Cs. These models are easy to use and can save companies from having to invest in T/D testing.

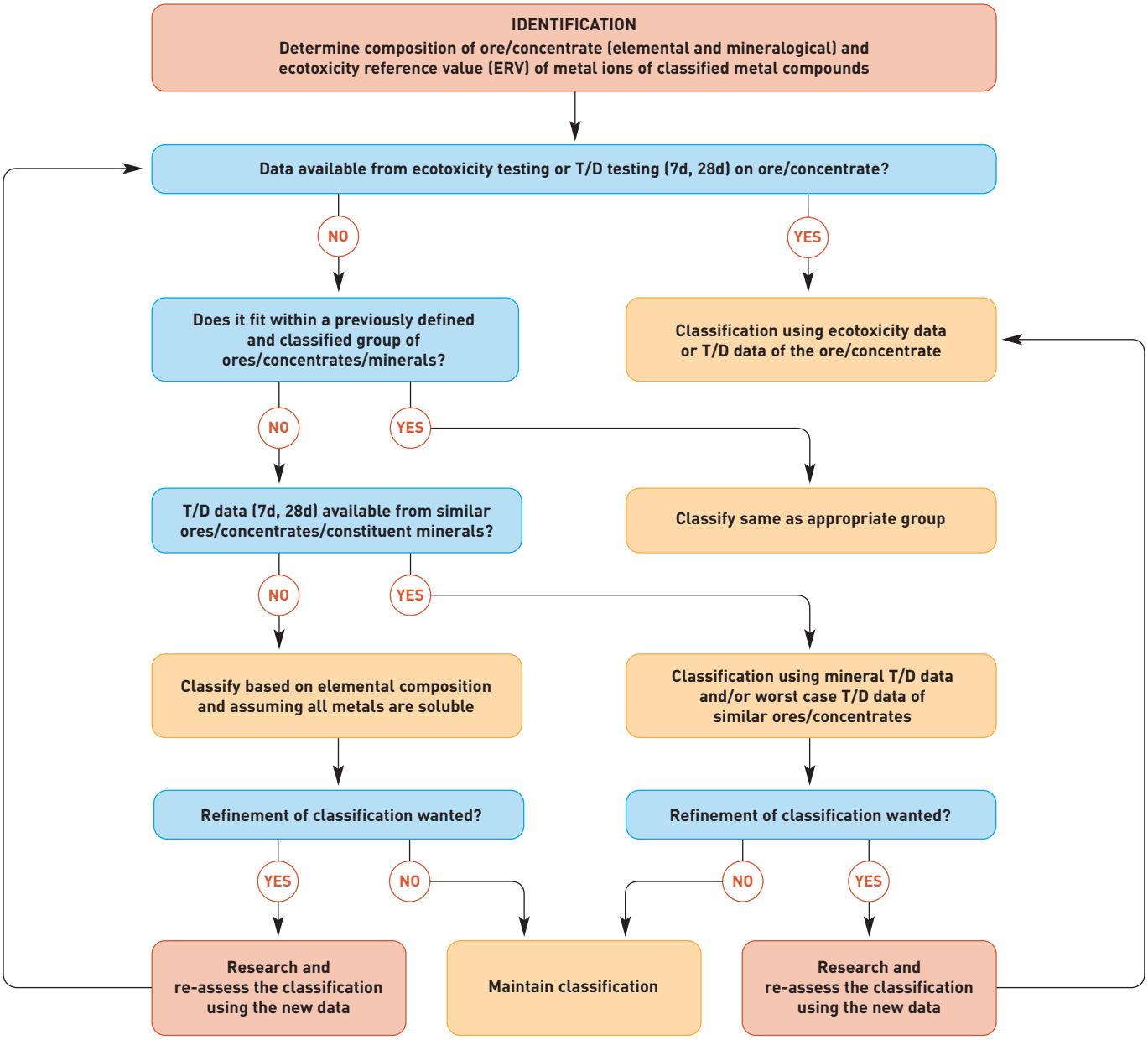
7

The 2012 guidelines to Annex V of the MARPOL Convention contain seven hazard criteria to identify materials harmful to the marine environment (HME). Six of these are relevant for O&Cs.

7 In case of variation in T/D results within the specific group of O&C, the worst case data are taken forward.

8 In case of variation in T/D results for a specific mineral, in the O&C the worst case data is taken forward.

Figure 1: General approach to assess the environmental hazards of O&Cs, relevant for transport regulations



3 Hazard classification of ores and concentrates

3.4 Assessment of human health end points

For most O&Cs, little or no acute or chronic toxicity data of sufficient relevancy or quality for use in human health hazard assessment is available. Performing acute or chronic animal tests using O&C samples is not recommended for the reasons stated in Section 3.3. Instead, the acute and chronic health hazards of O&Cs are largely based on bioaccessibility tests (solubility tests in artificial biological fluids). The toxicity of metal ions present in O&Cs largely depends on the bioaccessibility of the metal ions and the particle size distribution (critical for the inhalation route). Bioaccessibility is assessed by determining the solubility of metal ions present in metal-containing products such as O&Cs, according to various bioelution protocols. For the oral route, bioaccessibility of metal ions is assessed in gastric fluid, for example ASTM standard D5517-07. Bioaccessibility via the dermal route is assessed in synthetic sweat, for example EN 1811:2011, and bioaccessibility via the inhalation route is assessed in artificial lung fluid. The bioelution roadmap developed by Eurometaux (2014) is a useful reference document for more information on when and how to use bioelution tests.

Assessment of corrosion, irritation and sensitization related hazards is based on the guidance provided in the GHS.

3.4.1 Acute toxicity

Classification using available toxicity data on the O&C

Where acute toxicity data is available for an O&C and it meets the GHS quality and relevancy criteria, this should be used to determine the acute hazard classification of the O&C.

Classification using available bioaccessibility data on the O&C

Where O&Cs contain metals that are classified either on their own or in the form of certain inorganic compounds for acute toxicity end points, the bioaccessibility of these metal ions in the O&C should be further investigated as their solubility will influence their potential absorption and effects. Bioelution tests in the relevant media should be conducted. Acute hazards of the O&C are then assessed using the relative bioaccessibility data[9]. More guidance on how to conduct these tests and how to use those data for hazard classification is available in the bioelution roadmap (Eurometaux, 2014). Information on the acute hazard classification of metals and inorganic metal compounds can be found in the Meclas tool.

Classification using classification data from a similar O&C

If no toxicity or bioaccessibility data is available for an O&C, but the composition of the O&C is very similar to a group of O&Cs for which acute hazard classification data is available, the specific O&C can be classified by reading across the classification from the similar group.

Classification using bioaccessibility data from a similar O&C

If no bioaccessibility data is available for a specific O&C and read-across from a similar group of O&Cs is not possible, but bioaccessibility data is available for similar O&Cs, the classification of the specific O&C can be derived using the worst case relative bioaccessibility data of the relevant metal ions from the similar O&Cs.

Classification - worst case approach in absence of data

If no bioaccessibility data are available for a specific O&C or from similar O&Cs, and read-across from a similar group of O&Cs is not possible, a worst case classification approach is applied, assuming all relevant metal ions present in the O&C are bioaccessible.

Assessment of the acute toxicity of O&Cs can be carried out efficiently using the Meclas tool.

Under the IMDG Code, O&Cs that meet the criteria acute toxicity Category 1–3 are classified as dangerous goods Class 6.1.

Under the IMSBC Code, O&Cs that meet the criteria acute toxicity Category 1–3 are considered Group B-Class 6.1 cargoes, and O&Cs that meet the criteria Acute toxicity Category 4 by the dermal or inhalation route (as dust or as gas that evolved from the solid cargo when wet), or STOT – single exposure (STOT-SE) Category 1 by the inhalation or dermal route are classified as Group B – MHB.

9 Relative bioaccessibility is determined by comparing under similar test conditions the release of metal ion from the O&C in question with the release from appropriate reference substances (eg specific minerals or compounds known to be contained in the O&C).

3.4.2
Skin corrosion/irritation, serious eye damage/eye irritation, respiratory sensitization

The assessment of skin corrosion, skin irritation, serious eye damage, eye irritation and respiratory sensitization for an O&C should be made following the guidance provided in GHS using available test data on the O&C or on similar O&Cs. Where data is only available for the constituents this information is used to assess the above hazard end points for the O&C. In the latter case, the assessment can be made very efficiently with the Meclas tool.

Laboratory testing
In case of uncertainty in the outcome of the assessment, classifications can always be refined or validated by further research.

Under the IMDG Code, O&Cs that meet the criteria skin corrosion Category 1A, 1B or 1C are classified as dangerous goods Class 8.

Under the IMSBC Code, O&Cs that meet the criteria skin corrosion Category 1A, 1B or 1C are assigned to Group B - Class 8. O&Cs that meet the criteria skin corrosion/irritation Category 2, serious eye damage Category 1 or eye irritation Category 2A, respiratory sensitization Category 1 are considered Group B – MHB cargoes.

These hazards are not relevant to MARPOL Annex V.

3.4.3
Chronic toxicity

For the assessment of the chronic hazard endpoints a similar approach can be followed as described for the acute hazard endpoints (Section 3.4.1).

The IMDG code doesn't recognize chronic toxicity.

Under the IMSBC Code, O&Cs that meet any of the criteria STOT – repeated exposure (STOT-RE) Category 1 by the inhalation and/or dermal route, carcinogenicity Category 1A, 1B, mutagenicity Category 1A, 1B, reproductive toxicity Category 1A, 1B, are classified as Group B – MHB.

Under MARPOL Annex V, O&Cs that meet any of the criteria carcinogenicity Category 1A, 1B, mutagenicity Category 1A, 1B, reproductive toxicity Category 1A, 1B, STOT – repeated exposure (STOT-RE) Category 1, by the dermal or oral route (or if the route is not specified), must be assessed further to determine whether an HME classification should apply. This further assessment is described in Section 3.4.4.

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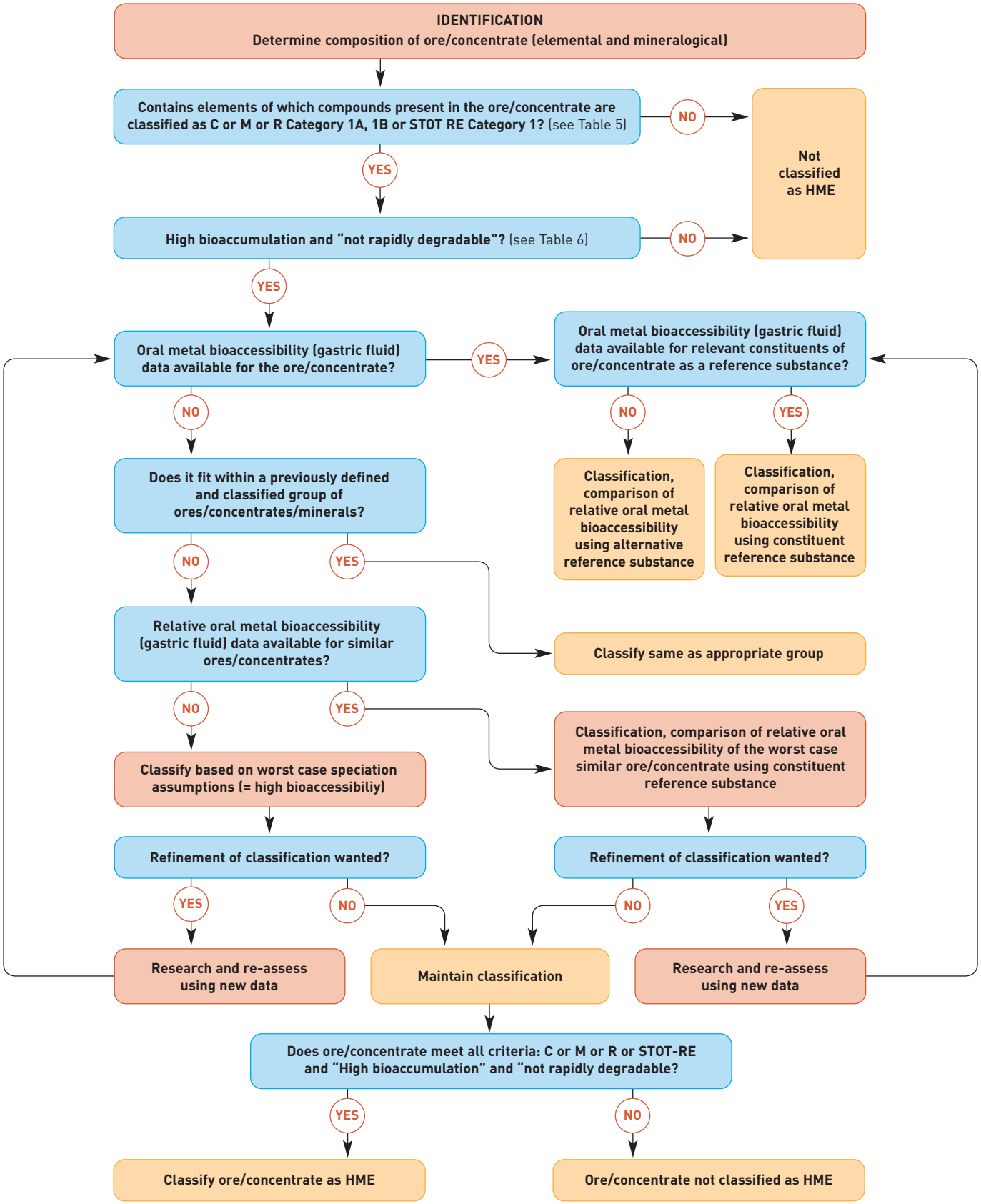
In paragraph 23 of its Plan of Implementation, adopted in Johannesburg in 2002, the World Summit on Sustainable Development (WSSD) encouraged countries to implement the GHS as soon as possible.

3 Hazard classification of ores and concentrates

Figure 2: Proposed general approach for the human health assessment of an O&C as HME by the oral route



3.4.4 MARPOL health-related HME critera

For the specific application to Annex V of the MARPOL Convention, a testing and assessment strategy to assess human health related HME hazards of O&Cs is presented in Figure 2 and summarized below. Figure 2 outlines the assessment of the human health related HME criteria for the oral route. A similar approach is followed for the dermal route.

Where an O&C contains metals that are classified, either on their own or in the form of certain inorganic compounds, as carcinogenic Category 1A/1B, mutagenic Category 1A/1B, reproductive toxicant Category 1A/1B or as STOT-RE Category 1 for the oral or dermal route or without specification of the exposure route[10], the properties "high bioaccumulation" and "not rapidly degradable" need to be assessed for these metal ions.

Bioaccumulation

The assessment of the potential for high bioaccumulation and of the rapid degradability property of metal ions, is complex and requires specific considerations for inorganic substances. The GHS and also the European Chemicals Agency's (ECHA) hazard classification guidance (ECHA, 2013) give specific guidance on this.

Table 5: Example of metal ions of which compounds are classified as carcinogen, mutagen, reproductive toxicant or STOT-RE

CLP ENTRIES	MUTAGEN REACH	CARCINOGEN REACH	REPRODUCTIVE TOXICANT REACH	STOT-RE REACH
Pb compounds			Category 1	Category 1
Ni in eg NiS, $NiSO_4$		Category 1[1]	Category 1[2]	Category 1[1]
Cd in eg $CdCl_2$	Category 1	Category 1	Category 1	Category 1
Co in eg $CoCl_2$	Category 1	Category 1[1]	Category 1	

(1) By inhalation only (not relevant to Marpol Annex V)

(2) Only for soluble nickel compounds

Table 6: Example of metal ions and their properties high bioaccumulation and not rapidly degradable

	HIGH BIOACCUMULATION REACH	NOT RAPIDLY DEGRADABLE RADAR ET AL, 2013
As-ions	NO	YES
Co-ions	NO	NO
Cd-ions	NO	NO
Ni-ions	NO	NO
Pb-ions	NO	NO

10 It should be noted that only the oral and dermal routes are relevant. Therefore metals and metal compounds which are classified for the above listed end points but only by inhalation are not relevant for HME assessment.

3 Hazard classification of ores and concentrates

The bioaccumulation of metals and inorganic metal compounds is a complex process and bioaccumulation data should be used with care. For most metals and inorganic metal compounds, the relationship between water concentration and bioconcentration factor (BCF) in aquatic organisms is inverse, meaning that "bioaccumulation" is not an intrinsic property. The "bioaccumulation" criterion is therefore not applicable to essential elements as their content in the organism is actively regulated through homeostatic processes. Assessing bioaccumulation for non-essential metals should be done carefully using a weight of evidence approach, using BCF studies performed in environmentally relevant concentrations in the test media.

Degradability

The method to assess the degradability of chemicals has limited or no meaning for metals and inorganic compounds as it is focused on the decomposition of organic molecules. An alternative method has therefore been developed. "Degradation" of metals and their inorganic compounds is evaluated by assessing the rate at which the reactive functional groups (the soluble metal ions) are removed from the water column through partitioning, precipitation and speciation processes. A detailed assessment for a range of metal ions has been made by Radar et al (2013). Additional information is available from the metal commodity associations listed in Section 5.

The assessment of the bioaccumulation potential and rapid degradability of metal ions has been made under the EU-REACH and CLP regulations – of which the guidance is in line with the GHS Annex 9 guidance.

The results of these assessments can be found at **http://echa.europa.eu/web/guest/information-on-chemicals/registered-substances**.

O&Cs that meet all three criteria:

- classified as carcinogenicity Category 1A/1B, mutagenicity Category 1A/1B, reproductive toxicity Category 1A/1B or STOT-RE Category 1 via the oral or dermal route or without specification of the exposure route
- having high bioaccumulation potential
- not being rapidly degradable

are classified as HME under MARPOL Annex V.

More details on the approach, research data and resulting classifications are available for various groups of ores and concentrates via the relevant metals commodity associations (see Section 5 for contact details). Some have also developed simple models, based on the approach described above, to predict the health classification of the O&Cs of their metal (eg Cu, Zn). Where these are available, the only information a shipper needs to make the required assessment is the elemental and mineralogical composition of their O&C. These models are easy to use and can save companies from having to invest in bioelution testing.

3.4.5 Physical hazards

Physical hazard end points are assessed by testing the O&C, according to the test guidelines of the UN's *Recommendations on the transport of dangerous goods – manual of tests and criteria* (2013) and the OECD test guidelines recommended in the UN's *Globally Harmonized System of Classification and Labelling of Chemicals (GHS)* (UN GHS 2011).

Classification cut-off values in the IMSBC Code (2013 edition) should be checked carefully, particularly for several of the MHB end points. For example, products are considered **corrosive to metals** under the GHS if the corrosion rate is 6.25mm/year or higher. Products with a corrosion rate of 4–6.25mm/year are however considered to be corrosive solids under the IMSBC Code and classified as Group B – MHB.

This means that a product may not be classified as corrosive to metals according to the GHS, but can be classified as a corrosive solid under the IMSBC Code. Another example of this type of anomaly relates to self-heating solids. Products are classified as self-heating solids in the GHS if during testing the increase in temperature over the oven temperature is 60ºC, while an increase in temperature of 10ºC is sufficient to trigger a classifications as Group B – MHB under the IMSBC Code. This means that a product may not be classified as a self-heating solid under the GHS, but may be considered a **self-heating** solid under the IMSBC Code.

Under the IMDG code, O&Cs that meet the criteria

- explosive solid Div 1.1-1.6 are classified as Class 1
- oxidizing solid Category 1-3 are classified as Class 5.1
- flammable solid-readily combustible Category 1-2 or flammable solid-self-reactive Type A-G are classified as Class 4.1
- flammable solid-pyrophoric as Class 4.2
- flammable solid-solids that evolve into flammable gas when wet Category 1-2 are classified as Class 4.3
- corrosive to metals Category 1 are classified as Class 8.

Under the IMSBC Code, O&Cs that meet the criteria flammable solids-readily combustible but fall beyond GHS Category 2 or flammable solids-self-heating but fall beyond GHS Category 2 or flammable solids-solids that evolve into flammable gas when wet but fall beyond GHS Category 3, or corrosive to metals but fall beyond GHS Category 1, are classified as Group B – MHB.

Under MARPOL Annex V, physical hazards are not considered.

Conclusions

4

4 Conclusions

Recent changes in maritime legislation pose challenges for the mining and metals industry. Several International Maritime Organization (IMO) regulations now require hazard assessment of solid cargoes, including ores and concentrates, transported in packaged form (IMDG Code) or in bulk (IMSBC Code and MARPOL Convention).

Fortunately the hazard assessment required by the IMO is based largely on the UN's Globally Harmonized System of Classification and Labelling of Chemicals (GHS), which the industry has many years of experience in dealing with. The GHS however has limited guidance for complex materials such as O&Cs and its application to these requires expert approaches, which have been developed by the mining and metals industry.

An overview of these approaches has been presented in this guidance document, which stresses that the assessment requires careful consideration of data in order to achieve consistent outcomes.

One particular resource that has been developed to assist in the consistency of classification is the Meclas tool, which contains much of the required reference data. Meclas allows efficient assessment of the classification at the various tiers of assessment described here. Its use helps to ensure the reliability and consistency of assessment that is consistent with industry good practice and responsible stewardship of its products.

Finally, companies are not alone in tackling this challenging assessment. Robust programs of work have been undertaken by the commodity associations listed in Section 5. Companies are recommended to contact them for support in the assessment of their cargoes.

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The International Maritime Organization (IMO) currently has 170 member states and three associate members and 77 international non-governmental organizations with consultative status.

Further information

5

5 Further information

Contact points

The following associations have worked collaboratively in developing the science and data on which the concepts outlined here are based. Their contribution to this document is much appreciated.

For further information on specific cargoes

Cobalt Development Institute
info@thecdi.com

International Aluminium Institute
tsesmelis@world-aluminium.org

International Copper Association
katrien.delbeke@copperalliance.eu

International Iron Metallics Association
shorner@metallics.org.uk

International Lead Association
binks@ila-lead.org

International Manganese Institute
kharlow@manganese.org

International Molybdenum Association
sandracarey@imoa.info

International Zinc Association
mgilles@zinc.org

Nickel Institute
egarman@nipera.org

World Coal Association
atomczak@worldcoal.org

Acronyms

BCF
Bioconcentration factor

BCSN
Bulk Cargo Shipping Name

CLP
EU Regulation (EC) No 1272/2008 on classification, labelling and packaging

CMR
Carcinogenic, Mutagenic, or Reprotoxic

ECHA
European Chemicals Agency

ERV
Ecotoxicity Reference Value

GHS (UN-GHS)
United Nations Globally Harmonized System of Classification and Labelling of Chemicals

GLP
Good Laboratory Practice

HERAG
Health Risk Assessment Guidance for metals

HME
Harmful to the Marine Environment (a MARPOL Annex V cargo criterion)

IMDG
International Maritime Dangerous Goods Code

IMSBC
International Maritime Solid Bulk Cargoes Code

LC50
Lethal Concentration 50% (the statistically derived concentration that can be expected to cause death in 50% of the animals in an experimental group)

LD50
Lethal Dose 50% (the statistically derived single dose of a substance that can be expected to cause death in 50% of the animals in an experimental group)

MARPOL
International Convention for the Prevention of Pollution from Ships

MECLAS
Metals Classification tool (online at: www.meclas.eu)

MERAG
Metals Environmental Risk Assessment Guidance

MHB
Material Hazardous only in Bulk (an IMSBC Code hazard criterion)

O&C
Ore and/or ore Concentrate

OECD
Organisation for Economic Co-operation and Development

REACH
EU Regulation (EC) No 1907/2006 on Registration, Evaluation, Authorisation and Restriction of Chemicals

STOT-RE
Specific Target Organ Toxicity (Repeated Exposure)

STOT-SE
Specific Target Organ Toxicity (Single Exposure)

T/D
Transformation Dissolution

UVCB
Substances of Unknown or Variable composition, Complex reaction products or Biological Materials

UWM
Unit World Model

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5 Further information

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The International Council on Mining and Metals (ICMM) was established in 2001 to improve sustainable development performance in the mining and metals industry. Today, it brings together many of the world's largest mining and metals companies as well as national and regional mining associations and global commodity associations. Our vision is one of leading companies working together and with others to strengthen the contribution of mining, minerals and metals to sustainable development.

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