This project has received funding from the European Union's Horizon 2020 research and innovation programme under
Grant Agreement number: **642477**

Project acronym: **¡VAMOS!**

Project title: ¡Viable Alternative Mine Operating System!

Funding Scheme: Collaborative project

D1.3: Zero-state environmental and geo-hazard evaluation criteria

Due date of deliverable: 31/07/2015 Duration: 42 Months
Actual submission date: 22/07/2015
Start date of project: 01/02/2015
Organisation name of lead contractor for this deliverable: GeoZS
Task Contributors: SMD, LaPalma

Dissemination Level		
PU	Public	☑
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

CREATIVE COMMONS
Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0)

This is a human-readable summary of the Legal Code (the full license).

You are free:

to Share — to copy, distribute and transmit the work

to Remix — to adapt the work

Under the following conditions:

Attribution — You must attribute the work in the manner specified by the author or licensor (but not in any way that suggests that they endorse you or your use of the work).

Noncommercial — You may not use this work for commercial purposes.

Share Alike — If you alter, transform, or build upon this work, you may distribute the resulting work only under the same or similar license to this one.

With the understanding that:

Waiver — Any of the above conditions can be **waived** if you get permission from the copyright holder.

Public Domain — Where the work or any of its elements is in the **public domain** under applicable law, that status is in no way affected by the license.

Other Rights — In no way are any of the following rights affected by the license:

- Your fair dealing or **fair use** rights, or other applicable copyright exceptions and limitations;
- The author's **moral** rights;
- Rights other persons may have either in the work itself or in how the work is used, such as **publicity** or privacy rights.

Notice — For any reuse or distribution, you must make clear to others the license terms of this work. The best way to do this is with a link to this web page.

Gorazd Žibret	Originating Work Package	GeoZS	researcher
Contributing Authors		Org	Function
Andrej Lapajne		GeoZS	researcher
Stef Kapusniak		SMD	manager
Internal peer reviewers		Org	Function
Internal approval		Org	Function
Jure Krivic		GeoZS	assistant director
External peer reviewer	Reviewing WP	Org	Function
Balazs Bodo		La Palma	WP1 leader
External approval		Org	Function
Balazs Bodo		La Palma	WP1 leader

Reviewing Quality Committee		Approved / Rejected	Date
Quality Manager	Jeroen van der Linden	Approved (Int. & ext. peer check)	30/07/2015
Technical Manager	Stef Kapusniak		
Authorised by Project Coordinator	Mary Vayou	Approved	25/09/2015

Revision	Comments / Description	By	Date	Status

Number of pages:	26
Number of annexes:	0

Contents

List of tables:

List of figures:

List of Recommendations:

1 Executive Summary

The aim of the deliverable D1.3 is to assess potential environmental and geohazard aspects related to submerged in-land as well as offshore mining, before any submerged mining actually takes place. iVAMOS! aims to economically extract ores in the areas where mining already took place before, so there is a high chance that environment is already contaminated to some extent. Having a clear assessment of the environmental baseline and the assessment of geohazards is an important part. It will allow better monitoring of impacts of submerged mining to the environment, and it will prevent environmental restoration claims of historic pollution against mining company.

Relevant documents were reviewed during this desk study, including current practices and available international legislation related to mining in the oceans, practices and available EU legislation related to mining in-land, including mining of sand and gravel below water table and hydraulic fracking. After this the consultations with different experts within and outside project consortia were conducted, and brainstorming exercises were performed. The topic is wide and extensive, a lot of legislative regulations exist and the iVAMOS! approach is completely new (no such practices exist at the moment with regards to metallic minerals). Therefore, the obtained list of recommended parameters, which is the main result of this study, might be incomplete, meaning that some parameters might be missing, or oppositely, some parameters might be less relevant for the iVAMOS! approach.

It is recommended to closely monitor the environmental impacts when performing the validation tests during the project lifetime. This will allow to confirm the most relevant set of parameters, as well as this will give a solid basis for the possible preparation of draft reference document on Best Available Techniques, which could be an important additional outcome of the iVAMOS! project.

2 Introduction

2.1 The VAMOS Project

Estimates indicate that the value of unexploited European mineral resources at a depth of 500-1,000 meters is ca €100 billion, however, a number of physical, economic, social, environmental and human constraints have as yet limited their exploitation. ¡VAMOS! will provide a new Safe, Clean and Low Visibility Mining Technique and will prove its Economic Viability for extracting currently unreachable mineral deposits, thus encouraging investment and helping to put the EU back on a level playing field in terms of access to strategically important minerals. Deriving from successful deep-sea mining techniques, the ¡VAMOS! mining solution aspires to lead to: Re-opening abandoned mines; Extensions of open-pit mines which are limited by stripping ratio, hydrological or geotechnical problems; and opening of new mines in the EU. ¡VAMOS! will design and manufacture innovative automated excavation equipment and environmental impact monitoring tools that will be used to perform field tests in four mine sites across Europe with a range of rock hardness and pit morphology.

VAMOS will:

1. Develop a prototype underwater, remotely controlled, mining machine with associated launch and recovery equipment.
2. Enhance currently available underwater sensing, spatial awareness, navigational and positioning technology.
3. Provide an integrated solution for efficient Real-time Monitoring of Environmental Impact.
4. Conduct field trials with the prototype equipment in abandoned and inactive mine sites with a range of rock types and at a range of submerged depths.
5. Evaluate the productivity and cost of operation to enable mine-ability and economic reassessment of the EU's mineral resources.
6. Maximize impact and enable the Market Up-Take of the proposed solutions by defining and overcoming the practicalities of the concept, proving the operational feasibility and the economic viability.
7. Contribute to the social acceptance of the new extraction technique via public demonstrations in EU regions.

2.2 Deliverable D1.3 - Zero-state environmental and geo-hazard evaluation criteria

2.2.1 Objectives

The task proposes standard zero-state environment and safety risks evaluation criteria and standards in order to properly address safety risks and environmental issues, and to determine the actual state of the environment before any submerged mining operations begin. This also includes hydrogeological assessment of adjacent aquifers. This deliverable in iVAMOS! represents a response to the request, made by the European Commission, as described within the call SC5-11-2014/2015 in the SC5-2014-15 work program: "Related environmental and safety risks should be assessed for all proposed actions."

Activities within D1.3 include evaluation of possible safety risks, environmental and geological hazards posed by submerged mining, definition of minimum environmental evaluation criteria and definition of standard measuring techniques and procedures. Two scenarios have been considered:
- submerged mining in-land,
- offshore mining.

D1.3 provides a list of recommendations for assessing natural conditions prior to test mining in order to establish baseline data, which will be performed in task T5.1 (Mining sites' preparation and field test planning), subtask ST5.1.1. One of the main objectives of this report is therefore to support subtask ST5.1.1.

The development of measurements specifications, methods and required parameters has been based on international standards, protocols, and EIA regulations.

2.2.2 Approach

This deliverable is based according to the consultations between the different participants within the VAMOS project consortium, with the aim to get the brief overview of the technology, which will be developed, and to define possible environmental impacts, geohazard risks and workers health and safety concerns.

Literature review was performed, including current legislative framework related to the deep sea mining, mining related EC regulations, as well as regulations and recommendations, which are valid for in-land submerged mining, which currently takes place (mainly sand and gravel open pits). We transferred such knowledge to the iVAMOS! - specific environment and made brainstorming exercises on how current practices can be valid in iVAMOS!-related environments, and what potential new issues might arise.

The final result is a list of all potentially relevant environmental, geohazard, and health and safety concerns. However, not all of listed concerns might be valid for every test site. The aim of this deliverable is, as described in a previous chapter, to support task 5.1.

2.2.3 Timetable

Release month	Scope in deliverable
06	release of the corrected version, based on the comments of the internal and external reviewers
06	release of the review version
01-05	consultations within the project partners

3 Review of relevant environmental legislative background

3.1 Offshore mining

3.1.1 Overview

Mineral grades on the sea floor are often higher than those found in-land, because some of the best deposits in-land have been exploited in the past. Two different environments in the sea may be distinguished as relevant from a raw materials perspective, the first being submerged parts of the continents, called continental shelf that can stretch as far as 1500 km from the shore. Average water depth on shelfs is 60 meters. Continental shelfs are geologically the same environment as land, and the same minerals that we find on land can we found on shelfs. The second marine environment is the oceanic crust, where water depth reaches up to 11 km (4200 m on average). Materials that can be mined on the seafloor are ferromanganese crusts, manganese nodules, polymetallic deposits of hydrothermal origin ("black smokers"), methane hydrate deposits and many potential uncovered resources.

The possibility of mining the deep seabed has been known for several decades (Lodge, 2012). At shallow depths and in calm water environments, seabed mining operations have been developed for a range of minerals, like diamonds, tin, ilmenite, magnetite, or gold. Recent improvements in riser technology, derived from the oil & gas industry, as well as advances in extracting technology, derived from the mining industry, allowed the exploitation of polymetallic nodules and seafloor massive sulphide deposits in much deeper water (www.smd.co.uk). The largest interest in deep-sea seabed mining exploration is on exploration of: polymetallic nodules, seafloor massive sulphides, cobalt-rich crusts and phosphates. One of the main driving forces in EU that causes an increased interest in the possibilities of deep-sea mining is to secure supply of raw materials that are critical for European manufacturing industries and consequently to ensure competitiveness for Europe as a whole.

Under **international law** the basic legal framework for deep-sea mining is set out in the United Nations Convention on "the Law of the Sea" (‘UNCLOS’) which was adopted in 1982 as modified by the Part XI Implementation Agreement. UNCLOS distinguishes between maritime zones under the jurisdiction of coastal States (internal and archipelagic waters, territorial sea, exclusive economic zone and continental shelf) and areas beyond national jurisdiction, namely the high seas and the seabed beyond the continental shelves of coastal States (called the “Area” in Part XI of UNCLOS) (Molemaker et al., 2014).

The International Seabed Authority (ISA) is an autonomous international organization based in Kingston, Jamaica and established under the 1982 United Nations Convention on the Law of the Sea and its 1994 Implementing Agreement relating to deep seabed mining. ISA is required to establish and keep under periodic review environmental rules, regulations and procedures to ensure effective protection for the marine environment from harmful effects which may arise during prospecting and exploration for marine minerals. The EU and Member States are members of ISA. The regulatory regime for deep-sea mining in the “Area” is not yet complete. Regulations on exploration have been adopted, while regulations on exploitation are currently being developed. The comprehensive set of rules, regulations and procedures issued by the International Seabed Authority present the so-called "Mining Code". The ISA Mining Code includes requirements to:

- Prevent, reduce and control pollution and other hazards to the marine environment, applying a precautionary approach and best environmental practices;
- Gather environmental baseline data against which to assess the likely effects on the marine environment;
- Establish comprehensive programs for monitoring and evaluating environmental impact;
- Include proposals for ‘impact reference zones’ (areas that are sufficiently representative to be used for assessment of impact on the marine environment); and

- Include proposals for ‘preservation reference zones’ (areas in which no mining shall occur to ensure representative and stable biota of the seabed in order to assess any changes in marine biodiversity).

To date, the Authority has issued Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area (adopted 13 July 2000, updated and adopted 25 July 2013); the Regulations on Prospecting and Exploration for Polymetallic Sulphides in the Area (adopted 7 May 2010) and the Regulations on Prospecting and Exploration for Cobalt-Rich Crusts (adopted 27 July 2012) (https://www.isa.org.jm/).

In international waters the resources of the deep seabed are administered in the following manner: scientific research is largely free of restrictions. Prospecting may be conducted only after the ISA has received a satisfactory written undertaking that the proposed prospector will comply with UNCLOS and the ISA rules, regulations and procedures and will accept verification of compliance by ISA. Exploration and exploitation may only be carried out under a contract with ISA and are subject to its rules, regulations and procedures. The regulations specify how an application is to be made for an approved plan of work as well as the form and content of the contracts for exploration. The concept behind the ISA regime is that economic benefits from deep seabed mining, possibly in the form of royalty payments, are to be shared for the ‘benefit of mankind as a whole’, with particular emphasis on the developing countries that lack the technology and capital to carry out seabed mining for themselves (Spicer, 2013).

Other international instruments of potential relevance to deep-sea mining include the Convention on Biological Diversity (adopted by the United Nations in 1992), to which the EU and the Member States are Contracting Parties, in terms of the protection of the marine environment. A range of legal instruments adopted under the auspices of the International Maritime Organization (http://www.imo.org/en) are of potential relevance to deep-sea mining. Finally, deep-sea mining activities may be affected by regional environmental agreements such as the OSPAR Convention (The Convention for the Protection of the marine Environment of the North-East Atlantic, adopted in 1992, last updated in 2006), the Barcelona Convention (77/585/EEC) which applies to the Mediterranean Sea and the Noumea Convention (1986; entered into force along with its two Protocols in 1990) which applies to part of the Pacific Ocean (Molemaker et al., 2014).

3.1.2 Approach to environmental implications

In EU legislation the topic of deep-sea mining is not yet specifically covered and deep-sea mining projects are not covered by the Environmental Impact Assessment Directive. EU law applies to maritime areas over which EU Member States have jurisdiction but it does not automatically apply to the overseas countries and territories of Member States. The Environmental Impact Assessment Directive (EIA) (2011/92/EU) does not explicitly refer to deep-sea mining. The directive that would apply also to deep-see mining is Strategic Environmental Assessment Directive (the SEA Directive) (2001/42/EC). EU measures that affect the deep-see mining activity are the Marine Strategy

Framework Directive (Directive 2008/56/EC), the Birds Directive (Directive 2009/147/EC), and the Habitats Directive (Council Directive 92/43/EEC) which may restrict or prevent deep sea mining in certain designated areas in order to protect birds and habitats (Molemaker et al., 2014). Environmental data relating to deep-sea mining is currently subject to the Environmental Information Directive (Directive 2003/4/EC). The Mining Waste Directive (2006/21/EC) does not apply to waste generated from deep-sea mining and the Waste Framework Directive (2008/98/EC) is designed for waste in general and is not fully appropriate for the management of waste generated by deep-sea mining. The recently adopted Maritime Spatial Planning Directive (2014/89/EU) will require the Member States to develop maritime spatial plans covering activities taking place in their 'marine waters' as defined in the Marine Strategy Framework Directive.

The Workshop on Environmental Management Needs for Exploration and Exploitation of Deep Sea Minerals was held in Fiji in 2011, organized by ISA in collaboration with the Government of Fiji and the SOPAC Division of the Secretariat of the Pacific Community. This workshop was the result of the increasing concerns about the potential environmental impacts of deep sea minerals exploration and mining. The output of this event was threefold: a draft template for an Environmental Impact Assessment (EIA) of deep seabed mining, an outline of the legislative and regulatory provisions that should form the basis of environmental management of deep seabed mining and the identification of capacity-building needs and methods by which these needs could be addressed (Isa Technical Study: No.10, 2011). At the time of writing this report (August 2015) there are detailed Regulations covering international waters for the exploration for polymetallic nodules, polymetallic sulphides and cobalt-rich crusts (ISA, 2010; 2012; 2013); as well as comprehensive Guidance to Contractors on the physical, chemical, geological and biological factors to be considered in baseline environmental surveys.

Detailed information on the technology, the economic, legal, geological, environmental, and social factors that are relevant for deep-sea mining operations is collected in the study to investigate the state of knowledge of deep-sea mining – Final Report under FWC MARE/2012/06 - SC E1/2013/04 (Molemaker et al., 2014).

3.1.3 Current operations and projects

With respect to active seabed exploitation, there are shallow mining operations in waters off Alaska for gold, around Malaysia and Indonesia for tin and magnetite and off the coast of Namibia for diamonds. Also, around 12 to 15 million tonnes of construction gravels are extracted off the UK coast.

Sea bed mining projects in international waters need to have a license issued by the ISA. This can be a prospecting license, an exploration license or an exploitation/mining license. Between 2001 and May 2014, the ISA approved 19 applications for exploration projects in the seabed area which covers 1 million km^2. In 2013 an additional seven applications covering an additional area of around 234,000 km^2, have been made to the ISA for exploration projects. They cover vast areas of the Pacific, Atlantic and Indian oceans. So far no exploitation/mining licenses have been issued by the ISA, but it has recently indicated that contracts for the exploitation of polymetallic nodules may be issued as soon as 2016 (Buthelezi, 2013). The two private companies that hold the majority of (exploration) licenses are Nautilus Minerals and Neptune Minerals. So far, two deep sea marine exploitation (or mining) licenses have been issued by National governments: one by the government of Papua New Guinea (the Solwara 1 Project in the Bismarck Sea) and one joint licence by the governments of both Saudi Arabia and Sudan (the Atlantis II Project in the Red Sea).

Currently, there are a range of mining operations at relatively shallow water depths (up to 140 m). Besides the Pacific region, applications have been made to explore for seabed minerals in the waters off Madagascar and Mauritius, and exploration is underway along South Africa's coast, in the Red Sea (Atlantis II Deep basin), Japan (Okinawa Trough, Izu-Bonin volcanic arc), New Zealand (iron sands off the North Island, Kermadec Trench, and Chatham Rise), Namibia (phosphorite/phosphates), and Western Australia. As regards areas under the coastal state jurisdiction of European countries three applications for exploration projects are currently pending: one in Italy, one in Norway and one in Portugal.

Nautilus Minerals Inc is the first company to explore the ocean floor for polymetallic seafloor massive sulphide deposits. In 2014, Nautilus was granted the first mining lease for such deposits at the prospect known as Solwara 1, in the territorial waters of Papua New Guinea, where it is aiming to produce copper, gold, and silver. The company has also been granted its environmental permit for this site (http://www.nautilusminerals.com).

3.2 Submerged mining in-land

Open-pit mining is a type of mining where the ore deposit extends deep in the ground, and overburden and waste rocks are removed to extract ore. These mines often occupy a large area of land for extraction and disposal of the overburden and waste. Because open-pit mining is employed for ore deposits at a substantial depth underground, it usually involves the creation of a pit that extends below the groundwater table. In this case, groundwater must be pumped out of the pit to allow mining to take place. A pit lake usually forms at some point in time after mining stops and the groundwater pumps are turned off (ELAW, 2010). Mining operations have impacts on the natural and human environments in each phase of the process. The impact assessment should account for all of the activities involved in the project, including the specific technologies in the project description for the proposed project and the alternatives.

By comparison with seafloor mining, inland submerged technique is simplified due to the absence of waves and currents. There is no need to deploy an expensive ocean-going vessel, and in most cases there is no fauna to interact with, because in most abandoned and flooded mines, the water is too acidic or stagnant and therefore unattractive to most creatures. There are thousands of mines across the EU that have stopped and are now filled with water. The reason for mine closure is usually not related to the exhaustion of the mineral deposits. It is more often due to a combination of stripping ratio increases, depth and associated energy requirements, and hydrological problems and pressure.

As a result substantial amounts of the ore, which cannot be extracted by using "conventional" open-pit mining techniques economically, will become available. The advantages of the iVAMOS! Approach:

- no need to pump water out of the pit, resulting in decreased operational costs;
- the slopes of the side walls can be steeper, decreasing the amount of waste rocks that needs to be removed.

The iVAMOS! approach (Figure 1) is to use different remotely controlled cutters to extract and crush the ore. Crushed ore is pumped in a suspension (slurry) to the shore for further processing to separate solid ore particles and water. Ore is transported to the processing plant, and water is returned to the pit. Special turbidity curtains can prevent spreading the suspension. Submerged machines are mainly electrical powered. The energy comes from the electricity grid (when available) or is generated on the shore by diesel-powered generators. Larger vessels for the sea-floor mining have the power of 3.2 MW, which is supplied through 6.6 kV cable. However, <50kW cutter heads will most probably be used for testing purposes at the iVAMOS! test sites. Some items on the submerged cutters are hydraulic powered on machine – but source of energy comes electrically through cables to subsea electric motor. Biodegradable oil is used for low volume hydraulic circuits.

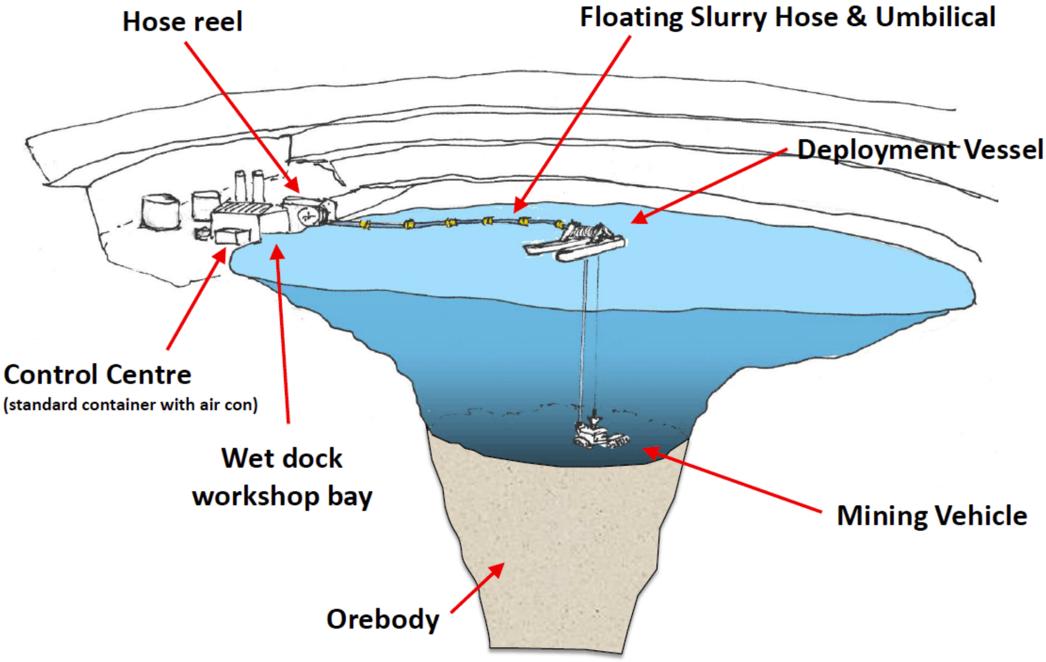

Figure 1. The iVAMOS! approach to extract ore in submerged in-land open-pit mines (figure taken from Kapusniak, 2013)

Inland submerged mining is particularly advantageous for ore deposits with the following characteristics (Kapusniak, 2013):

- Water table exists (pre-requisite);
- Near vertical/semi-vertical pipes (to get the stripping ratio advantage);
- Competent, stable and strong host rock;
- Medium strength ore;

- Low abrasive ore (preferable);
- Mines with high dewatering costs and/or hydrologically based stability problems;
- Blasting/dust nuisance adversely affecting neighbouring community.

Although there are currently no specific regulations or guidelines specified for inland submerged mining, they are generally covered by existing National and EU mining legislation, EC directives and other regulatory documents related to the environment apply (table 1). Furthermore the Environmental, Health, and Safety (EHS) Guidelines of the World Bank provide Good International Industry Practice (GIIP) that are applicable to underground and open-pit mining, alluvial mining, solution mining, and marine dredging. The document provides a summary of EHS issues associated with mining activities (and including ore processing facilities) which may occur during the exploration, development and construction, operation, closure and decommissioning, and post-closure phases, along with recommendations for their management (http://www.ifc.org/ehsguidelines). Since no reference document on Best Available Technology (BREFs) is available explicitly for submerged in-land mining, and there might be useful to prepare a draft of such document before the end of the iVAMOS! project.

Within the EU, the screening criteria for determining whether an environmental impact assessment must be conducted before an open-pit mine can be opened are set nationally. However, these generally require an EIA for all developments. Similar requirements will exist in non-EU countries. Because of the potential extent of environmental and social impact, and the requirement for consultation, the process of gaining planning permission in some circumstances may be protracted taking several years (EBRD, http://www.ebrd.com).

Table 1. The iVAMOS! relevant EC-level directives and regulation.

Directive	**valid aspects**
Environmental Impact Assessment Directive (2011/92/EU)	All, especially relevant to key impacts from land take during preparation, seismicity, noise, release to air, traffic, and surface and groundwater contamination; Member States must decide whether an EIA is required
The Strategic Environmental Assessment Directive (2001/42/EC)	All; Member States decide whether or not a plan or programme has significant effects
Water Framework Directive (2000/60/EC)	Abstraction of water and impacts due to water contamination, pollution of groundwater, water use
Mining Waste Directive (2006/21/EC)	Waste management as covered by MWD, major accidents, groundwater and surface water pollution, air impacts, treatment of hydraulic and other fluids during and after mining
Seveso II Directive (96/82/EC)	Major accidents involving dangerous substances (e.g. water pollution events)

Directives on Emissions from Non-Road Mobile Machinery (Directive 97/68/EC as amended)	Air pollution especially during drilling and power generation; lack of emission limits for combustion plants above 560 kW
IPPC Directive (2008/1/EC) and IED (2010/75/EC)	Emissions to air, water and soil
The Outdoor Machinery Noise Directive2000/14/EC	Noise
Air Quality Directive (2008/50/EC)	Air pollution and traffic impacts, releases to water
Environmental Liability Directive (2004/35/EC)	Land take, impacts on air
Noise Directive (2002/49/EC)	All kinds of noise

The Mining Waste Directive (2006/21/EC) specifies a number of requirements to ensure protection of the environment and human health, depending on the risks posed by the type of waste. Operators are required to provide a waste management plan for the minimisation, treatment, recovery and disposal for all extractive waste regulated by the directive (EBRD, http://www.ebrd.com).

The European Bank for Reconstruction and Development (EBRD) has developed the Sub-sectoral Environmental and Social Guidelines for mining, extractive industries and mineral processing to assist credit/investment officers in local financial institutions and other non-environmental experts and help in identifying major environmental activity risks (http://www.ebrd.com).

The EIA Technical Review Guidelines for Non‐Metal and Metal Mining were developed as part of a regional collaboration to strengthen environmental impact assessment (EIA) review under environmental cooperation agreements between the United States, five countries of the Central America and the Dominican Republic. It can be used as a basis for country‐specific adaptation to their EIA programs.

Among others the Guidelines address identifying and evaluating potential environmental social, cultural and economic impacts; and evaluating the full range of sustainable environmental measures to prevent, reduce and/or mitigate impacts. Environmental Impact Assessment starts with the description of the project to provide the context and sufficient detail about all the components of the project to support a credible assessment of impacts for both the proposed actions and reasonable and feasible alternatives. It provides the core data for forecasting potential environmental impacts, and for reducing, eliminating or mitigating those impacts. In the Guidelines, an Engineering design for metal and non-metal mines (the mining method, processing, the disposal of waste rock and tailings, transportation facilities, water control…) and the main elements of the proposed project and alternatives are described in detail (EIA, 2011).

The Guidebook for Evaluating Mining Project EIAs reflects many years of experience evaluating the environmental impact assessments (EIAs) for proposed mining projects around the world (ELAW, 2010). The subject of the Guidebook are the environmental impacts of large-scale mining projects involving the extraction of ore deposits such as copper, nickel, cobalt, gold, silver, lead, zinc, molybdenum, and platinum. Environmental and social impacts of mining, an overview of the EIA process and a process of reviewing an EIA for a Mining project are described in the Guidebook (ELAW, 2010).

The SARMa Guidelines for the environmental recovery of quarries in near river areas (Tomasaz, 2011) define a group of planning policies in the mining sector that will allow achieving acceptable environmental and landscape quality in the recovery of mining operation sites. This topic is also rigorously assessed in the case of hydraulic fracturing (Broomfield, 2012). Despite this method differs from the iVAMOS! concept, some aspects, especially related to the impact on groundwater, are analogous, and have been used in the formulation of recommendations.

4 Recommendations

The basis for preparing the list of recommendations about the relevant zero-state environmental and geotechnical parameters were EC level environmental regulations, regulations and procedures established by EIA and/or environmental agencies, regulations and practices, valid for mining in oceans and practices, valid for the existing submerged mining in-land (sand and gravel, hydraulic fracking). Recommendations, found in the aforementioned documents were adjusted to represent potential environmental concerns, relevant for submerged mining in-land. We also took into the account the fact that iVAMOS sites are sites of past mining activities, so the environment is already degraded. Table 2 summarise the major differences between conventional open-pit mining and iVAMOS! approach.

Table 2. The major differences between conventional open-pit mining and iVAMOS! approach.

issue	open-pit approach	iVAMOS! approach
extraction method	- mainly blasting, high environmental effects - large cutters or extractors	- crushing - smaller and more precise cutting
energy need	- high energy use for dewatering - mainly diesel-powered machines	- no need for dewatering, less energy is required - electrically powered machinery
workers health and safety	- workers work in areas where extraction takes place - risk of accidents because a lot of machinery is required	- no need for human presence in areas where extraction takes place
environmental impacts	- dust, noise, night time light emissions and vibrations - large amount of mining waste - spreading of metals and other pollutants in the suspension or solution because of dewatering - lower water table because of pumping - risks of oil spills from vehicles	- vibrations - potential negative effects on the underground water (including drinking water) - spreading of the suspension in the adjacent aquifers - spreading the metals and other pollutants in the form of solution in the adjacent aquifers - smaller risk of oil spill
land stability	- high risk of erosion of waste heaps - usually no problems with stability	- potential stability issues of submerged side walls - higher risks of rockfall or geotechnical accidents due to steeper side walls - high risk of erosion of mining waste heaps, because particles are small

landscaping	- large open pits, large mining waste heaps, high visual impacts	- smaller open-pits, smaller mining waste heaps, medium visual impacts
biota	- removal of vegetation - high probability that negative effects spread beyond mining area	- minimum removal of vegetation - low risks that negative effects spread beyond mining area
waste	- high amount of waste rock	- low amount of waste rock

A list of recommendations and measuring techniques is provided in the form of tables and relevancy to in-land and offshore mining is marked:

- Recommendations to determine the current state of the environment before any submerged mining operations begin;
- Recommendations to assess potential environmental and societal impacts of mining;
- Recommendations to assess/review potential accidental events and natural hazards; and
- Recommendations to the establishment of Workers Health & Safety standards.

The following tables should be used as a checklist before proceeding with extraction activities, and could be valid only for the full-scale submerged mining operations. Not all of the items are necessary or relevant for all sites, particularly in the case of low volume prototype testing.

4.1 Recommendations to determine the zero-state of the environment

Environmental evaluation	Measuring technique	Submerged mining in-land	Offshore mining
Geology			
- description of general geological and geomorphological setting	literature study, site visit by expert	x	x
- description of the regional geology – lithology and structure	literature study, site visit by expert	x	x
- cross sections and descriptions of the formations, major geologic structures and aquifers	literature study, site visit by expert	x	x
- description of the geochemistry of the various rock units	in-situ measurements, sampling & laboratory measurements, literature study, site visit by expert	x	x

Past exploration works			
- exploration drill-holes with the description of geological, hydrogeological, physically-mechanical and other measured parameters of lithological units and possible changes that could arise, geophysical investigations	literature study	x	
Waste rock, wall rock and ore characteristics			
- characterize the geochemistry of the waste rock, wall rock and ore in order to determine the potential for leaching of metals and other contaminants at the mine	in-situ measurements, sampling & laboratory measurements, literature study, site visit by expert	x	x
- geotechnical investigations (side wall and pit edge stability; the presence of unconsolidated sediments)	in-situ measurements, sampling & laboratory measurements, literature study, site visit by expert	x	x
Sediments			
- determine the chemical and geotechnical properties of the sediments, including measurement of soil mechanics and composition	in-situ measurements, sampling & laboratory measurements, literature study, site visit by expert	x	x
- description of underwater features (currents in case of off-shore mining site; sedimentation rates)	literature study, site evaluation by expert		x
Water quality at the site			
- water characteristics at various depths – temperature, particles, dissolved gas; chemical parameters of water (pH, Eh, dissolved metals and other dangerous substances if needed, like cyanide, petroleum)	in-situ measurements, sampling & laboratory measurements	x	x
Surface waters			
- identify all nearby rivers, streams, wetlands and other water bodies as well as the current uses of the water	literature study, site evaluation by expert, remote sensing	x	

- determine baseline rainfall, runoff and erosion characteristics as well as flooding characteristics of rivers and streams nearby and adjacent to the mine	literature study, site evaluation by expert, remote sensing	x	
- determine the boundaries of the watershed	literature study, site evaluation by expert, remote sensing	x	
- determine the nature and extent of pollutants discharged throughout the watershed	literature study, site evaluation by expert	x	
- determine the potential additional pollutants discharge from the existing mine	literature study, site evaluation by expert	x	
- monitor field parameters (pH, specific conductance, temperature, etc.) and laboratory analysed parameters (total dissolved solids, total suspended solids, selected trace metals, major cations/ anions and other potential pollutants identified in Risk assessment) upstream and immediately downstream of potential pollutant sources	in-situ measurements, sampling & laboratory measurements, monitoring, literature study, site visit by expert	x	
Groundwater			
- perform hydrogeological investigations: identification of water protection areas, possible abstraction wells in vicinity, determination of hydraulic conductivity and groundwater levels permeability, preparation of hydrogeological map	literature study, site visit by expert, consultation with the water authorities, hydrogeological mapping, drilling monitoring wells, in-situ measurements, sampling & laboratory measurements, mapping	x	
- monitor field parameters (ground water levels, pH, specific conductance, temperature, etc.) and laboratory analysed parameters (total dissolved solids, total suspended solids, selected trace metals, major cations/ anions, other potential pollutants identified in Risk assessment) in the monitoring wells upstream and immediately downstream of potential pollutant sources several times in the period of at least one hydrological year	in-situ measurements, sampling & laboratory measurements, monitoring, literature study, site visit by expert	x	

Air quality and climatic conditions			
- collection of climatic data for local weather stations (historic rainfall data, wind direction and speed, solar radiation, evaporation rates and temperature variations)	literature study, site evaluation by expert	x	x
- air monitoring upwind and downwind of the mining operation, sedimentation of particles	sampling & laboratory measurements, monitoring	x	
Ecosystems			
- determination of biological components and communities	literature study, site evaluation by expert	x	x
- identify whether the site or surrounding area has particular species that may be under threat	literature study, site evaluation by expert	x	x
- describe timing of important seasonal activities (nesting, breeding, migration, etc.) for species that could be affected by mining activities	literature study, site evaluation by expert	x	x
- collect data on the sea floor communities both in the exploration area and in areas that may be impacted by operations	in-situ measurements, sampling & laboratory measurements, literature study, site visit by expert		x
- assess pelagic communities in the water column and in the benthic boundary layer that may be impacted by operations	in-situ measurements, sampling & laboratory measurements, literature study, site visit by expert		x
- record in dominant species baseline levels of metals that may be released during mining	in-situ measurements, sampling & laboratory measurements, literature study, site visit by expert	x	x
- record sightings of marine mammals, other near-surface large animals (such as turtles and fish schools) and bird aggregations	in-situ measurements, sampling & laboratory measurements, literature study, site visit by expert		x
- determination of bioturbation and sedimentation	in-situ measurements, site visit by expert		x
- definition of possible restriction areas (Natura2000, ecological protected areas, Ramsar wetland areas) and restrictions according to spatial plans, visibility in local environment - landscaping	literature study, consultations with authorities, GIS	x	x

Socio-economic conditions			
- population and cultural characteristics	literature study	x	
- societal susceptibility to mining (social licence for mining)	survey within local population, expert evaluation	x	x
- regulatory framework in the country, where mining is taking place	literature study, expert evaluation, consultation with authorities	x	x

4.2 Recommendations to assess potential environmental and societal impacts of mining

Environmental evaluation	**Measuring technique**	**Submerged mining in-land**	**Offshore mining**
Impacts on water quality			
- the potential effects of particle-laden plumes in the water column	monitoring, water screens	x	x
- increased total dissolved solids, trace metals, and other pollutants	monitoring	x	x
- effects on underground waters and adjacent aquifers (chemical and physical changes)	monitoring	x	
- acid mine drainage potential	monitoring, evaluation by expert, planning, remote sensing	x	x
- drawdown or rising of groundwater levels	monitoring	x	
- contamination of groundwater and surface water with chemicals and oil	monitoring, evaluation by expert, planning	x	x
Impacts on air quality			
- particulate matter transported by the wind as a result of transportation of materials	monitoring	x	x
- gas emissions from the combustion of fuels in stationary and mobile sources	monitoring	x	x
- noise at surface	monitoring, complaints	x	x

Impacts on fish and wildlife			
- impacts of the mining operation on surrounding ecosystems (impacts to living organisms, removal or deterioration of adjacent habitats, disturbance of migration routes, disturbance of sediment which can create a sediment plume)	monitoring, planning	x	x
- impacts on pelagic communities	monitoring, recording		x
- the toxic chemicals and fuel used in mining, their effects on ecosystems in the case if they are released by the mining process	monitoring, recording	x	x
- impacts of suspended particles in water (impact on organisms, creation of additional sediment plumes or sediment release to adjacent surface aquifers, geochemical changes due to changes in redox conditions); abrasion effects on machinery (higher possibility of failure)	monitoring, recording	x	x
- loss of substrate	monitoring		x
- disruption of migration routes/nesting/breeding activities by presence of humans, light and noise from transportations and mining operations	monitoring, recording, evaluation by expert	x	x
- potential local or regional loss of endemic or endangered species / creation of replacement habitats	evaluation by expert	x	x
- impacts of underwater light, vibration	monitoring, evaluation by expert	x	x
- impacts of night time light emissions	monitoring, evaluation by expert	x	
Impacts on geology			
- the physical destruction of the seabed by mining	monitoring		x
- the potential for catastrophic slope failures	monitoring, planning	x	
- the destruction of unique geological features, fossils or minerals	planning	x	x

Impacts on social values			
- impacts on livelihoods	monitoring, planning	x	x
- impacts on public health (surface and groundwater contamination)	monitoring, planning	x	x
- increased traffic and truck trips (safety, noise, exhaust)	monitoring, planning	x	x
- impacts of underwater light, vibration	possible complaints evaluation	x	x
- vibration, tremors, fractures on buildings	monitoring, possible complaints	x	
Impacts of mining waste			
- mining waste geotechnical stability	monitoring, planning	x	x
- mining waste stable chemically	monitoring, planning	x	x
- prevention of dusting	monitoring, planning	x	

4.3 Recommendations to assess/review potential accidental events and natural hazards

Environmental evaluation	**Measuring technique**	**Submerged mining in-land**	**Offshore mining**
Hazardous substances leakage or spillage – release of toxic ore, fuel and other hazardous material; oil or hydraulic fluid leaks from machinery	planning, regular maintaining	x	x
Fire and explosion (air emissions and runoff of contaminants)	planning, regular maintaining	x	x
Evaluation of possible impacts of natural hazards (earthquakes, severe weather...)	planning	x	x
Accidents on transport routes (fuel, ore transportation etc..), pathways through protected areas	planning, regular maintaining	x	x

4.4 Recommendations to the establishment of workers health and safety

Environmental evaluation	Measuring technique	Submerged mining in-land	Offshore mining
- health status of workers	physical examination	x	x
- regular control of harmful materials and release from waste dumps (air, water particles, dissolution) at the site	monitoring	x	x
- ensure systematic maintenance, service and testing of equipment and devices	planning, regular maintaining	x	x
- ensure protection against fire	planning, regular maintaining, BAT	x	x
- measurements of concentrations of harmful substances in the air at the site and ensure preventing of spreading them	planning, monitoring, BAT	x	x
- personal safety equipment should be available	planning	x	x
- safe access to the site, which should enable fast and safe evacuation routes	planning	x	x
- restriction of movement in the mining area by unauthorised personnel and wild animals	planning	x	x
- transport and access routes and loading areas should be dimension and arranged so that they ensure free-flowing and safe traffic	planning, maintaining	x	x
- transport routes should be visibly marked	planning	x	x
- workplaces should be organised in the way that workers are secured against bad weather conditions and falling objects; the workers should not be exposed to harmful noise and hazardous fumes, steam and dust	planning	x	x
- ensure adequate equipment for evacuation and rescue, which should be allocated at accessible places and set for immediate use	planning	x	x
- non-flammable, non-toxic and non-harmful use of hydraulic fluids	planning, maintaining, BAT	x	x
- plan for the mobilisation of rescue services and civil protection services in the case of major accidents	planning, informing	x	x

5 Conclusions

This deliverable presents the iVAMOS! relevant zero-state environmental and geo-hazard criteria. It contains a list of recommended set of parameters, which should be addressed before any underwater in-land extraction process takes place. Such list of measured parameters is useful during and after extraction takes place, not only to protect environment and society, which might be affected because of mining, but also the company - holder of mining permits, to avoid any financial or other claims because of environmental degradation, which may not be the result of new mining activities, but rather a consequence of past mining activities or possible other anthropogenic activity or natural phenomena. Environment, natural hazards and accidents, as well as workers health and safety have been taken into account.

Authors acknowledge that the list of parameters is exhaustive. However, not all parameters are relevant for every submerged mining activity and/or site, so the actual and relevant site-specific list of parameters should be prepared for every mining site separately, in consultation with relevant national and local authorities, experts and mining companies. In the iVAMOS! project, such process for the selection of site-specific relevant parameters will be done within the field tests in task T5.1 for all test sites.

6 References

Barcelona Convention - Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, 1976, amended in 1995 (77/585/EEC; protocols 81/420/EEC, 83/101/EEC, 84/132/EEC 2004/575/EC and 2010/631/EU)

Broomfield, M., 2012, Support to the identification of potential risks for the environment and human health arising from
hydrocarbons operations involving hydraulic fracturing in Europe. AEA Technology plc, ED57281- Issue Number 17, 191 pp. with annexes.

Buthelezi M, ‘UN may license first seabed mining in 2016, but enviro scepticism lingers’, Mining Weekly, 7 June 2013, http://www.miningweekly.com/article/un-may-license-firstseabed-mining-operations-in-2016-but-enviro-scepticismlingers-2013-06-07-1.

Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment.

Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment.

Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC.

72 Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning.

EIA Technical Review Guideline: Non-Metal and Metal Mining - Regional Document prepared under CAFTA DR Environmental Cooperation, 2011, 196 pp.

Program to Strengthen Environmental Impact Assessment (EIA) Review

Environmental Law Alliance Worldwide (ELAW), Eugene OR 97403, 2010. The Guidebook for Evaluating Mining Project EIAs, 110 pp.

European Bank for Reconstruction and Development (EBRD). Sub-sectoral Environmental and Social Guidelines: Mining Open Cast, 17 pp. http://www.ebrd.com/downloads/policies/environmental/mining/mining-open.pdf

European Union 2006, Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC - Statement by the European Parliament, the Council and the Commission, http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:102:0015:01:EN:HTML

International Finance Corporation, 2007. Environmental, Health and Safety Guidelines, Mining. http://www.mizuho-fg.co.jp/english/csr/environment/equator/pdf/ehs_mining_eng.pdf

ISA, 2010. Technical Study No. 6: A Geological Model of Polymetallic Nodule Deposits in the Clarion-Clipperton Fracture Zone. International Seabed Authority.

ISA, 2012. Decision of the Assembly of the International Seabed Authority relating to the Regulations on Prospecting and Exploration for Cobalt-rich Ferromanganese Crusts in the Area. ISBA/18/A/11.

ISA, 2013. Periodic review of the implementation of the plans of work for exploration for polymetallic nodules in The Area, IISBA/19/C/9/Rev.1.

Kapusniak, S., 2013. Remotely Controlled Mining Equipment for Subsea and Submerged Inland Deposits. 23rd World Mining Congress, August 11-15, 2013, Montreal, Canada.

Lodge, M. W., 2012. The Common Heritage of Mankind. International Journal of Marine & Coastal Law, 27 (4), 733–742. doi: 10.1163/15718085-12341248.

Molemaker, R.J., Gille, J., Kantor, E., van Schijndel, M., Pauer, A., von Schickfus, M., van Elswijk, J., 2014. Study to investigate the state of knowledge of deep-sea mining Final Report under FWC MARE/2012/06 - SC E1/2013/04, Rotterdam/Brussels, 19 November 2014, 194 pp.

Noumea Convention – The Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (1986).

OSPAR Convention – The Convention for the Protection of the marine Environment of the North-East Atlantic, Paris, 22 September 1992, updated 24 July 1998, 9 May 2002, 7 February 2005 and 18 May 2006, 33 pp.

Spicer, W. Commentary: Seabed mining still lacks ground rules, The Northern Miner: The Global Mining Newsletter, 2013-01-16 and 2013- 01-23. (http://www.northernminer.com/news/commentary-seabed-mining-still-lacks-ground-rules/1001995484/)

Tomasaz P.B., Marasmi C., Ricciardelli, F., Rizzati A.R., Romagnoli, M., Pelosio, A., 2011. Guidelines for the environmental recovery of quarries in near river areas (gravel and sand open pit). SARMa project, 20 pp. http://www.sarmaproject.eu