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Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

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## SCOPING ACTIVITIES

## Scoping Paper on the Impacts of wastes and other matter in the marine environment from mining operations

**Submitted by the Chairman of the Correspondence Group**

## INTRODUCTION AND BACKGROUND

1 At the 40th session of GESAMP in September 2013, GESAMP and UNIDO organized a side-event workshop on "*Discharge of mine tailings and coastal runoff in the marine environment*". The workshop addressed three related topics:

- Industrial submarine tailings disposal (STD), also known as deep-sea tailings placement (DSTP);
- Industrial riverine tailings disposal; and
- Artisanal tailings disposal, which is predominantly if not entirely riverine.

2 GESAMP agreed that the issues raised were specific to land-based sources of pollution, that is, discharge to the marine environment via pipes or rivers, and seabed mining were beyond the scope of GESAMP's activities for this particular initiative.

3 Presentations and panel discussions at the workshop highlighted gaps in international governance, as it is not clear which international agency should take the lead on these issues. GESAMP also acknowledged the importance of adequately describing the receiving environment, as well as a number of knowledge gaps, including the behaviour of slurries underwater, physical smothering, ecotoxicological effects and recovery times. GESAMP agreed to develop a scoping paper for possible activities to fill knowledge gaps and to inform further action by the Sponsoring Organizations.

4 GESAMP noted that the issues raised at the side event are of great interest to a number of the Sponsoring Organizations including IMO, UNIDO, UNEP-GPA and IAEA-MEL. IAEA-MEL kindly offered to host a workshop on the topic in Monaco. Another option would be to hold the workshop in a country where mining operations using riverine or submarine tailings disposal are underway or being planned.

5 The London Convention and Protocol (LC/LP) has also been interested in riverine and submarine disposal of tailings and associated wastes, including cooperation of the LC/LP Secretariat at IMO with UNEP-GPA in gathering information on the issue. The LC/LP Secretariat commissioned a report on the issue, which was submitted to the LC/LP Scientific Groups and discussed at the LC/LP meetings in November 2013. The report (Vogt, 2013) is available at:

http://www.imo.org/en/OurWork/Environment/LCLP/minetailings/Documents/Mine%20Tailings%20Marine%20and%20Riverine%20Disposal%20Final%20for%20Web.pdf

6 The Scientific Groups agreed there is a need for international guidance and/or codes of conduct to be developed, but like GESAMP noted there is a governance gap and it is not clear which international body should take the lead.

7 The November 2013 meetings of the LC/LP also noted the interest of other international agencies in the issue, as well as GESAMP's decision to prepare a scoping paper. The LC/LP agreed to establish an intersessional correspondence group with the following terms of reference:

- Jointly with the Secretariat, establish coordination and liaison with the GESAMP and UNIDO process in relation to the scientific scoping paper and the related workshop, and explore the need for and possible sources of funding for further work;

- Develop an inventory and understanding of the scope of the LC/LP and other international bodies;

- Gather information on best practices, existing guidance and other issues of marine and riverine disposal of mine tailings around the world; and

- Prepare and submit a progress report to the next joint session of the Scientific Groups to be held in New Orleans, United States, in May 2014 and a report to the 36th Consultative Meeting of the London Convention and the 9th Meeting of Contracting Parties to the London Protocol in November 2014, to provide the governing bodies with further information regarding the subject. This report should include recommendations for potential next steps.

8 In May 2014 the LC/LP Scientific Groups reviewed a progress report of the correspondence group. They were also informed that Chile had established, in 2013, a National Deep Sea Tailings Placement Initiative. This is a research program established by mining companies to conduct research to close knowledge gaps relating to DSTP and evaluate it as an alternative to land disposal. The Scientific Groups were also provided with a summary of the International Workshop on Deep Sea Tailings Placement held in Chile in January 2014 (see annex, below).

9 At the May 2014 meeting, the delegation of Peru offered to host a workshop on STD, and the delegation of Chile offered to provide some support.

10 Thus, there appeared to be interest in STD by a wide range of stakeholders, as well as support for GESAMP's involvement in addressing information gaps with the aim of supporting the development of international guidance and/or codes of conduct for assessing and implementing STD.

11 Although GESAMP considered industrial riverine tailings disposal at its 40th session, only four mines, one in Indonesia and three in Papua New Guinea (PNG), currently conduct riverine tailings disposal on an industrial scale (Vogt, 2013). Another mine, the closed Panguna gold/copper mine on Bouganville Island, PNG, is taking steps toward re-opening and may be considering riverine disposal. This is not clear, however, and UNEP has agreed to assist with remediation of environmental damage caused by the mine's former riverine discharge, which would appear to make resuming the practice unlikely. Because industrial riverine disposal is no longer likely to be permitted in most countries, it is not considered further in this scoping paper.

12 As was demonstrated at the GESAMP side event, riverine tailings disposal from artisanal mining is widespread and of serious environmental concern. The issue of artisanal tailings disposal, however, has very different dimensions than industrial STD, and will require a different approach to address through international action. It is unlikely to be feasible to address both industrial STD and artisanal tailings disposal simultaneously through a single international process. Because the other activities described above focus on industrial STD, it is recommended that GESAMP consider the two issues separately, in stages. Therefore this scoping paper focuses on industrial STD.

## SUMMARY OF THE ISSUE

### Use of STD

13 Mining often generates huge quantities of tailings, the solid waste left after the commercially valuable materials in the raw ore are extracted. Most mines dispose of tailings on land. A small number of mines, however, have in the past or currently are using STD. At least 16 mines, in eight countries, currently practice STD (Table 1).

**Table 1 Mines currently practicing STD (Vogt 2013; Kvassnes and Iversen 2013). In some cases the quantities are permitted quantities, actual discharges may be less.**

| Country | Mine | Discharge rate (t/y) | Commodity |
|---|---|---|---|
| Chile | Huasco | 1,200,000 | Iron |
| England | Cleveland Potash | 1,800,000[1] | Potash |
| France | Gardanne | Not available | Aluminium |
| Greece | Agios Nikolaos | Not available | Aluminium |
| Indonesia | Batu Hijau | 40,000,000 | Copper/gold |
| Norway | Sibelco Nordic, Stjernøya | 300,000 | Nepheline syenite |
| Norway | Bokfjorden | 4,000,000 | Iron |
| Norway | Skaland | 40,000 | Graphite |
| Norway | Rana Gruber | 2,000,000[2] | Iron |
| Norway | Hustadmarmor | 500,000 | Calcium carbonate |
| Norway | Quartz Corp | 21,000 | Quartz |
| Norway | Norcem | ~3,000 | Calcium carbonate |
| Papua New Guinea | Lihir | 4,000,000[3] | Gold |
| Papua New Guinea | Ramu Nickel | 5,000,000 | Nickel/cobalt |
| Papua New Guinea | Simberi | Not available[4] | Gold |
| Turkey | Cayeli Bakir | 11,000,000 | Copper/zinc/lead |

[1] Discharge is filter/centrifuge cake rather than tailings in the conventional sense. An unknown proportion of this quantity is probably backfilled into the mine rather than discharged to the sea; current situation not known.

[2] Permit allows 1,250,000 t/y, discharges of 2,000,000 t/y occurred under exemption, and application lodged for new permit for 2,500,000 t/y (Kvassnes and Iversen 2013); status of new permit not known.

[3] Quantity is tailings discharge via pipe; mine also discharges 40,000,000 t/y offshore by barge (Vogt 2013).

[4] Mine approved, uncertain if STD operations are underway.

14 It is possible that some mines using STD are not included in Table 1. For example, Kvassnes and Iversen (2013) list two mines (Quartz Corp and Norcem) using STD in Norway that are not identified in Vogt (2013). Thus it is possible that other mines using STD have not been identified in existing reviews.

15 STD is also being considered, proposed, or planned for new mines. Vogt (2013) identifies five mines in Norway proposing STD, as well as two in PNG. One of the mines in Norway, the Nussir copper/gold/silver mine, received approval for STD in 2014 and expects to commence operation in 2015 or 2016 (Nussir ASA, 2014). The current status of the other mines proposing STD in Norway was not reviewed. In PNG, STD has been approved for a new gold mine at Woodlark Island (Kula Gold, 2014a, b), and is apparently still being actively considered for the proposed Simberi gold mine (Marengo, 2014). The National Deep Sea Tailings Placement Initiative in Chile is evaluating STD as an alternative to land disposal. Thus, it appears that proposal for STD may increase in the coming years.

16 The Goro Nickel mine in New Caledonia disposes its actual mine tailings on land, however it discharges the wastewater from ore processing into deep ocean water via a pipeline. Some phosphate mining and processing operations also discharge waste water into the marine environment. Discharges of process water pose some similar environmental and governance issues as the discharge of solid tailings slurries. This scoping paper does not investigate the submarine discharge of effluents other than mine tailings solids, however it may be useful to include such practices in the scope of future GESAMP activities.

**STD Practices and Rationale**

17 STD is generally accomplished by mixing the mine tailings with seawater to form a slurry, which is then pumped via pipeline to the discharge point. In the past, mines using STD have sometimes discharged the slurry at the shoreline or in shallow water near shore, often leading to major environmental impacts in these zones (Dold, 2014; González *et al*., 2014; Vogt, 2013; Shimmield *et al*., 2010).

18 STD practice has evolved toward discharge at greater depths. The Huasco iron mine in Chile, for example, initially discharged tailings directly at the shoreline, but moved the discharge to 25 - 35 m depth (Dold, 2014, González *et al*., 2014), and has prepared an environmental impact assessment (EIA) for discharge at 100 - 200 m depth (Dold, 2014; Vogt, 2013).

19 Current practice in STD is to discharge the tailings slurry on a steep slope with the intent that the slurry flows down slope as a density current to a final resting place at greater depth. Both the discharge point and the final depositional area are intended to be at sufficient depth to prevent both solid and dissolved material from being retained in, or upwelling to, the photic zone (Figure 1). In the case of the Cayeli Bakir copper/zinc/lead mine in Turkey, tailings are discharged at a depth of 275 m into the anoxic zone in the Black Sea.

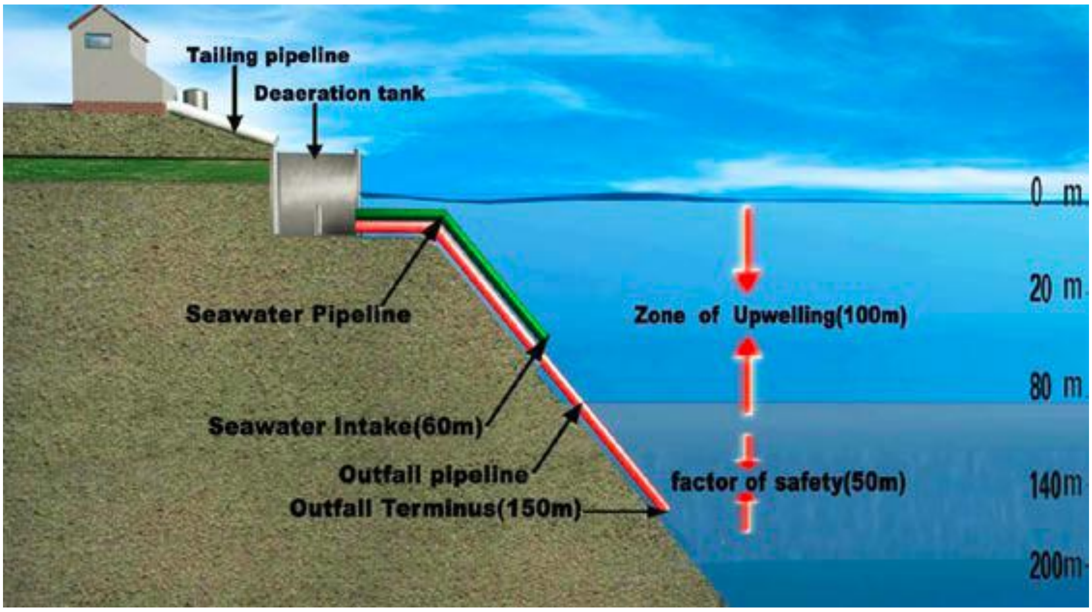


**Figure 1 Conceptual diagram of STD at Ramu Nickel mine, PNG (Source: Ramu Nico 2014)**

20 STD is attractive to mining proponents because it is usually less costly than obtaining, constructing and maintaining land-based tailings disposal sites. This sometimes creates the perception that low cost is the primary or only motivation for proposing STD. A number of other arguments to justify consideration of STD instead of land-disposal, however, deserve consideration on a case-by-case basis:

- Disposal of tailings to the marine environment, with minimal exposure to the atmosphere, reduces the risk of acid mine drainage (AMD), whereby oxidation of tailings releases acidic leachates, often including high levels of bioavailable dissolved metals, into freshwater systems;

- Many mines using or considering STD are located in areas that have steep topography, regularly experience high rainfall events, and/or are tectonically active. These pose significant technical and engineering challenges for the design and maintenance of safe land-based disposal facilities;

- The above-mentioned challenges of topography/rainfall/tectonics tend to restrict land disposal options to relatively flat land that is often more valuable for other uses. At the now-closed Misima gold mine in PNG, for example, land with a topography suitable for tailings disposal and confinement was valued for subsistence and market gardening by island residents (Shimmield et al., 2010). Tailings disposal can alienate large areas of land for these other uses on very long time scales, if not in perpetuity;

- Land-based disposal sites, especially those that require tailings dams, may need to be managed/maintained in perpetuity. Some countries lack capacity to effectively enforce this. Regardless of national capacity, there have been a number of incidents where failure of tailings disposal/containment facilities has caused severe environmental damage (Vogt, 2013); and

- Failure of tailings dams poses high environmental, and human health and safety, risks, which are reduced or eliminated by STD.

21 STD systems often discharge the tailings slurry at the head of submarine canyons to promote the flow of density currents down slope. This is intended to mimic natural turbidity flows, which deposit deep-sea fans at the base of the continental slope (Figure 2). Even in highly mineralised catchments, however, the geochemistry of the tailings is unlikely to be the same as natural sediments derived from weathered and eroded rocks (Dold, 2014; Koski, 2012; Shimmield *et al*., 2010). However, natural turbidity flows could accelerate the burial of tailings under natural sediment post-mining above rates of deposition from the water column, depending to the extent to which the mine alters the catchment and downstream mineralogy and sedimentary regime. Furthermore, the more or less continuous discharge of tailings represents a very different disturbance regime than natural, episodic, turbidity flows.

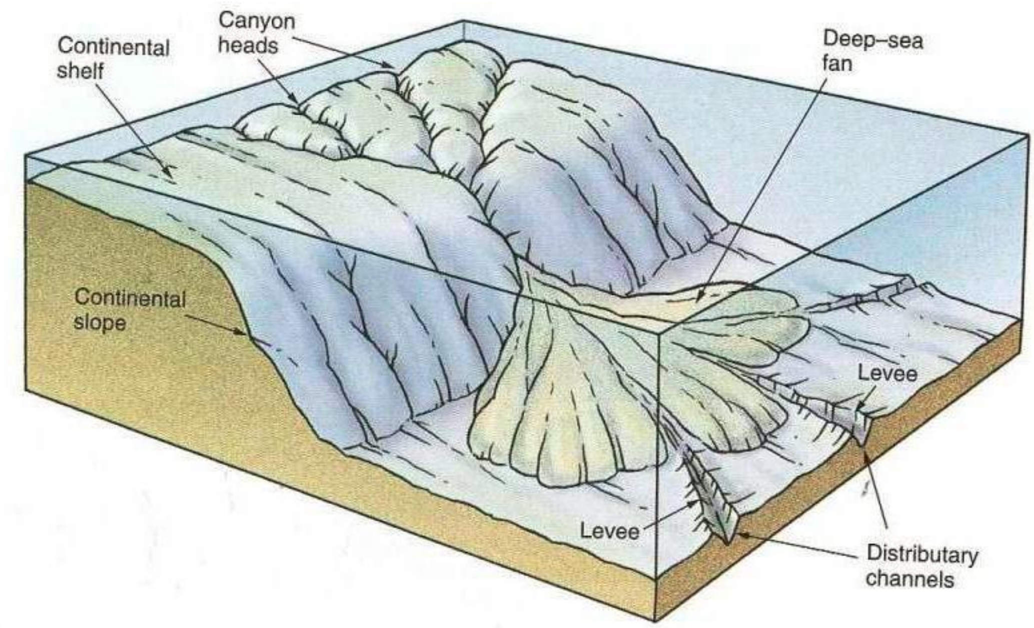


**Figure 2 Conceptual drawing of STD mimicking natural turbidity flows (Skotte 2011)**

## Environmental Effects of Submarine Tailings Disposal

22 Past STD operations discharged into shallow water have often had major environmental impacts in these zones (see reviews by Dold, 2014; Vogt, 2013). For example, studies of deposited tailings from the Island Copper mine in Canada, which ceased discharge in 1994, showed deposition of tailings at shallower depths than predicted, reduced biodiversity, and accumulation of copper in bivalves (Dold, 2014 and references therein). An Environment Canada report in 1996 concluded that STD from the mine had a widespread and permanent impact on the benthos, leading to a ban on STD in Canada (Dold, 2014).

23 Modern STD schemes are intended to discharge tailings at depth to prevent impacts on productive surface waters either directly or due to the transport of tailings and derived contaminants by upwelling or surface currents. Nonetheless, deep-sea STD has a range of unavoidable or potential adverse environmental effects, including *inter alia*:

- Smothering and other direct physical impacts on benthos in the turbidity flow path and depositional footprint;

- Long-term or permanent alteration of benthic habitat, preventing recovery of biological communities;

- "Shearing" of plumes of sediment or dissolved contaminants from the downward turbidity flow, and their dispersal at intermediate depths;
- Similarly, upwelling of plumes into shallower water, with attendant potential biological and human health impacts;
- Toxicity and/or bioaccumulation of metals made bioavailable in the water column or sediments;
- Toxicity of process chemicals released with the tailings;
- Risks of discharge pipe breakage, leading to unplanned shallow-water discharge; and
- Effects of nanoparticles released with the tailings.

*Smothering and other direct physical impacts*

24 The large quantities of tailings discharged inevitably smother the benthos in the final deposition area, and will also have direct physical impacts on benthos in the path of the downward turbidity flow. This is analogous to the destruction of terrestrial habitats in land-based tailings disposal. All STD schemes have a base case of severe direct impact on a defined benthic footprint. Monitoring shows that in some cases the footprint of tailings deposition is as predicted by modelling; in other cases the footprint has been much larger. Decision-making regarding the acceptability of a proposed STD scheme is thus heavily dependent upon model predictions of the location and size of the final deposition area, as well as the subsequent transport of deposited tailings to other locations. This highlights the need for a detailed understanding of the receiving environment and the appropriate selection and application of hydrodynamic models used in EIA.

25 In addition to smothering, deep-sea STD is likely to have other direct physical impacts on benthic communities. The discharge pipeline itself will have a physical footprint that will damage the benthos. This is no different from any offshore outfall scheme and can be managed by appropriate design of the pipeline corridor and construction methods. There are also likely to be scouring effects along the downward route of the tailings stream. Due to the continuous nature of discharge, these will differ from episodic natural turbidity flows, and their ecological significance can only be determined on a site-specific basis.

*Habitat alteration*

26 The deposition of tailings from deep-sea STD schemes inevitably results in the alteration of the receiving habitat. If tailings are deposited on naturally hard-bottom habitats there will be a complete alteration of the benthic substrate to a soft-bottom one. Modern STD schemes, however, are designed with the intent that the final resting place of the tailing is in a natural sedimentary basin. Even so, the stratigraphy, grain size distribution, solid-phase and pore-water trace metal concentrations, and other critical features of the sedimentary habitat are likely to be profoundly altered (Dold, 2014; Shimmield *et al*., 2010).

27 During mine operation, this habitat alteration is largely irrelevant, as ongoing disturbance from continuous tailings disposal will outweigh the effects of habitat alteration. After mine closure, recovery of the benthic community will depend among other things on the severity of habitat alteration, and whether natural sediments more like those that existed before mining cover the tailings, and on what time scale.

28 Rates of re-colonisation of deposited tailings after disposal ceases are likely to be highly variable and dependent upon the natures of both the tailings and the receiving environment. Recolonisation of tailings is likely to occur on the order of at least years (Jensen, 2009, cited in Vogt, 2013; Shimmiel, *et al*. 2010), although some biota, such as meiofauna, may recolonise to a level indistinguishable from natural sediments on shorter time scales (Gwyther *et al*., 2009). Recovery to a benthic community similar to that existing before STD, however, is likely to take much longer. At the Misima mine disposal site, for example, there appeared to be rapid recolonisation by some taxa, but there were profound differences in both the sedimentary habitat and benthic communities 3-1/2 years after STD ceased (Shimmiel *et al*., 2010).

29 Recovery to a benthic community approximating that which existed before STD is likely to depend to a considerable degree on the "capping" of the tailings with natural sediments. Some authors (e.g. Shimmiel *et al*., 2010) have noted the low natural sedimentation rates in the deep sea and concluded that recovery through burial of tailings under natural sediment could take centuries to millennia. This does not take into account the high rates of sedimentation that may occur at the foot of submarine canyons via natural turbidity flows. Such turbidity flows are, however, unpredictable and therefore difficult to take into account in an environmental impact assessment.

*<u>Shearing and upwelling</u>*

30 The intent of modern STD schemes is that the discharged tailings stream moves as a coherent flow down-slope to deposit the tailings solids at a final, naturally retentive, resting place, so that the tailings and any associated contaminants are retained in a relatively small area below productive surface waters. In at least some cases this objective has not been achieved. In what has been termed "shearing", some particulate and/or dissolved components of the descending tailings plume can separate from the main descending turbidity flow and spread laterally at intermediate depths. At the Lihir mine in PNG, for example, an estimated 10-30% of the tailings discharge is estimated to move laterally from the main density current (NSR, 2001, cited in Shimmiel *et al*., 2010). Horizontal transport of tailings waste in the water column potentially distributes adverse effects over greater distances, and to other ecological compartments (e.g., pelagic vs. demersal systems) than predicted on the basis of a coherent down-slope flow.

31 STD schemes may also fail to achieve the objective of depositing tailings into deep water below the productive surface layer, because upwelling and/or surface mixing returns the waste to the surface. Shimmiel *et al*. (2010) concluded that upwelling was not an issue at the Misima and Lihir mines in PNG because the island coastlines were too short to generate wind-driven upwelling. By contrast, Erdinger (2012) reports that tailings from the now-closed Minahas Raya gold mine in Indonesia were transported upward from the discharge point at 82 m depth, resulting in major impacts from sedimentation and metal contamination on fringing reefs. Erdinger (2012) identified the relatively shallow depth of discharge, and gentle slope of the seabed, as factors that increased the risk of tailings returning to the surface.

*<u>Toxicity and bioaccumulation</u>*

32 One of the key risks with most if not all STD schemes is the release of toxic contaminants. One of the advantages of STD is to prevent AMD and the attendant release of bioavailable dissolved metals. In at least some instances, however, metals are still released from the disposed tailings into the water column and/or sediment pore water, and taken up by organisms (Brewer *et al*., 2012; Dold, 2014; Erdinger *et al*., 2008; Lasut *et al*. 2010; Shimmield *et al*., 2010). The metals released and their concentrations are specific to each individual ore body and the mining and processing methods. Arsenic, copper, lead and mercury are common contaminants of concern, but a range of other metals may also be released.

33 The characteristics of the receiving environment are also critically important with regard to the risk of bioavailable metals release. The reduction-oxidation (redox) status of the water body is of particular importance , as metals can be released either by introducing reduced minerals such as sulphides into an oxidising environment, or oxidised minerals into a reducing one (Dold, 2014). Dold (2014) advocates a mineralogical and geochemical assessment of prospective tailings in the context of the proposed receiving environment as the first step in environmental impact assessment of STD proposals.

34 Mine tailings may also contain additive process chemicals that pose an ecotoxological risk. Probably most common is the discharge of cyanide used in ore processing at gold mines. The Misima gold mine was one such mine. At Misima, tailings were diluted with seawater prior to discharge to reduce the cyanide concentration, but the concentration still exceeded national water quality standards at the boundary of a mixing zone that varied from 2.5 km in width at a depth 42 m above the outfall to 1 km 488 m below the outfall (Shimmield *et al*., 2010). This is a much larger mixing zone than would typically be accepted for industrial wastewater discharges in shallower water. Other mines use various treatment methods to reduce cyanide concentrations in the tailings. At the Lihir mine, for example, tailings are mixed with iron-rich residues to neutralise the cyanide (Shimmield *et al*., 2010).

*Other impacts*

35 STD schemes may have a range of other environmental impacts, like any waste discharge into the marine environment. The high turbidity, and potentially toxic contaminants, may cause fish and other organisms to move away from the area. Brewer *et al*. (2007), for example, found that fish were less abundant overall near the Lihir tailings discharge than at reference sites further away, and 17 of the most common species were also less abundant at the discharge site, through three species were more abundant near the discharge.

36 As with any offshore waste outfall, STD pipelines will have a direct physical impact in the pipeline corridor footprint, and there will always be a risk of pipeline failure. A break in the STD pipeline at Misima, for example, resulted in the discharge of tailings directly onto the reef (Shimmield *et al*. 2010). These and other potential effects of STD schemes are in general not substantively different from other offshore wastewater outfalls, and can be assessed and managed with industry- standard practices.

37 An emerging issue, raised in a letter from Friends of the Earth Norway to the LC/LP Secretariat in January 2014, is that the grinding of ores during extraction and process generates a fraction of nanoparticles. The letter expressed concern about the potential effects of these nanoparticles in the marine environment when discharged with the tailings through STD. This scoping paper has not examined this issue further.

**Current assessment/Management practices**

38 All STD operations are subject to national EIA and regulatory approval processes in the home country. There does not appear to be a robust international approach to providing guidance, voluntary or otherwise, on good practice in STD. The LC/LP does not strictly apply to STD operations because the tailings are discharged from a pipe, it may still fall under the general obligations of the LC/LP Parties. While the LC/LP specifically addresses the disposal of wastes and other matter from vessels, platforms and other man-made structures at sea, the view from IMO's legal service has been that it is for Parties to determine where the boundary should be drawn between dumping as defined (and regulated internationally) and land-based discharge (regulated nationally or, in some cases, regionally). In other words, the question of whether a subsea tailings outfall could or could not be considered to be a man-made structure at sea has not so far been universally resolved, and may be interpreted differently by different administrations. In addition, the LC and LP do apply in waters of national jurisdiction. The LP also contains a provision to stress that "Each Contracting Party shall at its discretion either

apply the provisions of this Protocol or adopt other effective permitting and regulatory measures to control the deliberate disposal of wastes or other matter in marine internal waters where such disposal would be "dumping" or "incineration at sea" within the meaning of article 1, if conducted at sea."…Hence, there is a mechanism to ensure regulatory equivalence in that regard.

39 Kvassnes *et al*. (2009) concluded that STD is allowable under the EU Water Framework Directive if the receiving waters are classed as a 'Heavily Modified Water Body', but note that this would require rehabilitation of the water body after mine closure. Furthermore, a number of sources (Dold, 2014; Reichelt-Brushett, 2012; Shimmield et al. 2010; Skotte 2011; Skei et al. 2009, 2010, 2014) have developed advice on best management practice for STD. These were summarised by Vogt (2013; see box).

40 Advice on management practices in STD tends to be more specific in relation to engineering and operational practices, for example de-aeration of the tailings before discharge or the solids content of the slurry. There appears to be a lack of guidance on other aspects of STD management. For example, while the need to adequately characterise the receiving environment is universally accepted, there does not appear to be consensus on the minimum data requirements to, for example, characterise variability in the depth of the mixed layer or provide adequate data for developing and validation hydrodynamic models of tailings plume transport. Prisetiahadi and Yanagi (2008), for example, found that the outfall depth of 82 m at the Minahas Raya gold mine did not take into account the seasonal variability in the density discontinuity (pycnocline), resulting in the upwelling of tailings onto the fringing coral reef.

**Best Management Practices in STD (compiled from various sources by Vogt 2013)***

Technical and Engineering Considerations

- Tailings should not contain soluble toxic compounds. The flotation agents and flocculation compounds should be easily degradable. Effort should be expended into minimizing use of chemicals in the ore separation process.
- Cyanide management plans should be developed and implemented such that minimum levels of cyanide are used to achieve acceptable levels of separation, and specific treatment processes should be applied to reduce cyanide compounds resulting from the ore separation process prior to discharge.
- The mine tailings slurry should not contain air bubbles. A system to reduce entrainment of air into the tailings discharge pipe should be installed to avoid air bubbles bringing fine particles to surface waters.
- The tailings slurry should be a minimum of 30% solids.
- The tailings should be mixed with seawater to achieve a density of the suspension exceeding the density of the seawater where the tailings will be disposed. The intent is for the tailings plume to sink towards the bottom, with the finer particles moving as a density current to the seafloor instead of dispersing higher up in the water column.
- To help control fine particles, flocculants can be added to the mine tailings slurry.
- The outfall discharge pipes should be engineered to meet the conditions of the physical environment at the shoreline and to the depth of discharge.
- A low energy environment is needed to reduce the potential for pipe breaks.
- Experience has shown that the pipeline slope must be at least 12 degrees to avoid the risk of tailings build-up at the discharge point. The rate of discharge is also an important factor to minimize the possible blockage of the discharge.
- The discharge location should be below the pycnocline, which is the depth at which water density increases rapidly due to changes in temperature or salinity. The intent is that the tailings plume does not mix with surface waters. Where the decline in temperature is responsible for the increase in density, the pycnocline is also the thermocline. If an increase in salinity is responsible for the increase in density, then the pycnocline is the halocline. Finally, the discharge should be below the euthropic zone, which is the zone of net primary productivity, below which insufficient light penetrates for photosynthesis.

Considerations For Disposal Site Selection

- Suitable bathymetry and physical oceanography---steep submarine slopes, submarine canyons, or natural channels beyond fringing coral reefs; deposition zone such that mine tailings are not dispersed
- Suitable biological site avoiding important spawning grounds, or commercial or local fishing grounds—not a genetic source population or spawning ground for local fish populations Soft bottom depositional area
- Anoxic conditions—desirable to reduce rates of leaching of toxics from the mine tailings
- Absence of upwelling and seasonal overturning, and absence of currents that can disperse the initial plume of mine tailings away from the intended deposition site or cause turbidity plumes from the settled tailings to spread outside of the intended footprint

Permit Conditions

- Permits or licenses to discharge should contain specific conditions capturing the above practices and should also include requirements for monitoring and assessment. Specific criteria should be established such that the results of monitoring can be assessed against criteria and standards.
- Monitoring is an important element as monitoring results allow adjustments and optimalization of discharge design to minimize environmental effects. A monitoring programme should be comprehensive to assure that the effects of the sea disposal develop as planned. If the environmental responses develop differently, actions should be taken and if necessary the disposal should terminate.

* Note: The author did not propose or establish these as best management practices, but rather collated them from other sources.

**Information gaps**

41 There are a number of information gaps that could usefully be addressed at an international level to develop improved guidance on STD:

- A more complete register of current STD operations, proposals, and their status;
- The results of environmental monitoring of past and current STD operations compared to the predictions of the project's EIA, and reasons for significant discrepancies;
- Better understanding of current practices in modelling the behaviour of discharged tailings slurries, including shearing and upwelling of both the solids and soluble fractions. It is not clear at the level of this scoping paper whether existing models are adequate or if further development is needed;
- Guidance on assessing the potential impacts of the release of toxic substances, metals in particular. EIAs of STD typically use model predictions of concentration fields in comparison to applicable water and sediment quality standards, sometimes supplemented by ecotoxicity testing of test materials intended to represent the ultimate mine-generated tailings. Mestre *et al*. (2014) note that available ecotoxicity data are based on shallow-water organisms. They point out that hydrostatic pressure in the deep sea affects the structure and function of enzymes, structural proteins, and cell membranes, and therefore processes such as osmoregulation and nerve conduction. Thus, available ecotoxicity data may not adequately reflect the effects of toxicants in the deep sea. Mestre *et al*. (2014) conclude there is an urgent need to study the effects of pressure on the toxicity. Mestre *et al*. (2014) acknowledge the practical difficulties of conducting ecotoxicity tests on deep-sea fauna, and recommend a first step of investigating the effects of pressure on toxicity of substances to standard test species. In the interim, it may be useful to develop guidance on the likely effects of pressure on ecotoxicity and/or safety factors that might be applied to existing guidance; and
- Deep-sea organisms and ecosystems are in general more poorly understood than shallow ones. This results in inherently greater uncertainty in EIA. It would be useful to better understand which are the most important uncertainties to be addressed, both in EIAs of STD proposals and by further research.

**OUTCOME OF THE INTERNATIONAL WORKSHOP**

42 Following the offer by the Government of Peru, the GESAMP International Workshop on the impacts of mine tailings in the marine environment was held on 10 and 11 June 2015 at the Melia Hotel in Lima, Peru. The Workshop was hosted by the Maritime Authority of Peru (DICAPI) and organized as a joint IMO-GESAMP activity. The Workshop was supported by the International Network for Scientific Investigations of Deep-Sea Ecosystems (INDEEP)[1], the Deep Ocean Stewardship Initiative (DOSI)[2], the Research Council of Norway (Norges Forskningsråd, NFR), the Chilean and Peruvian mining industry associations and the Peruvian Coast Guard.

43 The Workshop was attended by more than 90 participants, including relevant researchers, policy makers, coastal and marine managers and industry. The final programme, list of participants and presentations given can be downloaded at:

[1] http://www.indeep-project.org/
[2] http://www.indeep-project.org/deep-ocean-stewardship-initiative

http://www.dicapi.mil.pe/taller/en/down_workGesamp.html. The overall objectives of the Workshop were:

- to provide a synthesis of the current understanding of the impacts of marine disposal of mine tailings and to identify gaps in scientific knowledge in this field; and
- to develop partnerships to address issues through further work.

**Workshop conclusions and recommendations**

44 The Workshop proceedings are currently being prepared by the IMO-LC/LP Secretariat in cooperation with GESAMP. The main conclusions and recommendations are set out in the following paragraphs.

45 Several gaps in the current science and information/understanding of deep water ecosystems as well as the behaviour of mine tailings in the marine environment were noted and specified in detail, for example:

- marine organisms normally used for toxicity testing are from the upper stratified layers of marine water, not the deep sea. There is a need to develop standard sediment and aquatic toxicity tests that use species from deeper water, and preferably in situ, which is however both complicated and costly;
- there is a need to better understand the behavior of mine tailing slurries, including from empirical work and modeling;
- the effects of Deep Sea Tailings Placement (DSTP) in the complete water column and at far field need to be better understood;
- there is a need to better understand physical and chemical behavior of sediment plumes which shear off at all depths; and
- to understand the effects of mine tailings in the marine environment, there is a need to integrate multiple scientific oceanographic disciplines, with proper baselines being noted as crucial to understand the effects.

46 The Workshop also discussed what constitutes best practice beyond the engineering aspects, e.g. ecosystem evaluation. The importance of monitoring was also highlighted.

47 The Workshop noted that there were strong correlations between the issues identified for DSTP and those identified for wastes produced during deep sea-bed mining and that any further work or studies should address both activities as much as possible to reduce effort and costs.

48 Finally, the Workshop discussed the necessary steps to move the issue forward. These included:

- generate basic knowledge. We are early in this aspect, and more knowledge about both the marine ecosystems in question and the behaviour and impacts of mine tailings are needed;

- there is a need to 'socialize' the process, beyond only engineering issues;

- appropriate regulatory frameworks should be implemented and lessons should be learnt from these experiences;

- operational practices for mining processes and discharges must be adapted to the specific conditions of DSTP; and

- monitoring of the marine environment will be key to confirm any risk assessments made. This includes long-term monitoring after closure. Some examples were given where this kind of knowledge is now being gathered, but monitoring of deep-sea environments is a costly activity and the examples are consequently rare.

49 In summary, the Workshop was highly successful, bringing together the core of the experts involved in the research and regulatory work in relation to mine tailings disposal in the marine environment.

50 The final report of the Workshop is currently under preparation by the GESAMP Office and the LC/LP Secretariat. A draft may be presented at the 42nd session of GESAMP and finalized intersessionally.

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**Options for continued involvement by GESAMP: establishment of a working group**

51 Building on the scoping paper and the outcomes of the workshop, GESAMP will need to discuss how to best take the issue forward, bearing in mind that it will also be discussed at the next meeting of the LC/LP governing bodies in October 2015.

52 Given the initial interest of the Sponsoring Organizations, and the cross-cutting nature of the issue, there seems to be potential for the establishment of a Working Group, should GESAMP find this feasible. In 2013-2014, several Sponsoring Organizations expressed an interest, including IMO, UNIDO, IAEA, UNEP and UNDP. If there is support from one or more of the Sponsoring Organizations, Terms of Reference could be developed intersessionally (possibly following the meeting of the LC/LP governing bodies). For this purpose, draft Terms of Reference and a draft work plan can be found at annex 2 to this scoping paper.

**Action requested of the GESAMP**

53 GESAMP is invited to note the information provided and the forthcoming full proceedings of the international workshop, and decide if the establishment of a Working Group would be desirable.

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## ANNEX 1

**Summary of the International Workshop on Deep Sea Tailings Placement (DSTP) held in Viña del Mar, Chile, from 22 to 23 January 2014**

### Research Guidance

1 The development of guidance for carrying out specific research programmes was identified as an important need to close the gaps in the technical and scientific knowledge required to evaluate DSTP. The guidance should include both research design and implementation.

### Framework for using the results of the research

2 The purpose of the DSTP initiative is to develop the scientific and technical knowledge needed to evaluate the human health and environmental viability of the technology. Even if the technology is found to be viable, a decision will still have to be made on whether or not to implement the technology.

### Conceptual framework

3 Participants were asked to provide their inputs to develop a conceptual framework for using the results of the research to compare the relative risk of DSTP versus land-based disposal of tailings.

### Guidance for Socially Responsible Research

4 The initiative recognizes that some of the research must be conducted at potential DSTP sites and that, as a result, it may impact the local community. Responsible management and oversight of the research studies must therefore go beyond the technical methodological issues and consider the social impact of conducting the research.

### Strategy of communication and outreach

5 Participants were asked to provide their inputs to develop guidance for an effective strategy of communication and outreach to the communities where the field research will take place.

### Guidance for ongoing stakeholder engagement

6 DSTP is an issue that is of interest to a diverse group of stakeholders. In order for the initiative to be successful, it is essential that stakeholders are involved in the process and understand its purpose, which is to generate information and evaluate technologies, not to implement them.

### Barriers or concerns

7 Participants were asked to provide their inputs to identify possible barriers or concerns to consider during the development of a stakeholder engagement strategy.

**The path forward**

8 Three main tasks will be carried out in the coming years. The first one is to engage stakeholders as part of the process. The second one is to engage well recognized scientists to develop a robust research programme. The third one is to make the research programme and all subprogrammes identified during the knowledge workshop available.

9 The DSTP initiative is committed to answer identified questions as long as necessary, taking into account that possible answers could not comply with the vision established in the road map.

10 It was envisaged that the stakeholders' engagement and the scientific research programme would allow to create the conditions to make a productive and unbiased discussion at the political and regulatory level.

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## ANNEX 2

### Draft Terms of Reference and work plan for a GESAMP Working Group on the environmental impacts effects of wastes from mining operations disposed at sea[3]

**Terms of reference**

1 The GESAMP study should:

.1 Identify and provide a better understanding of potential environmental impacts of marine disposal of tailings or other wastes from mining operations. Such wastes may arise from land-based or (deep-)sea-base mining operations. The impacts could include, but not limited to those identified in the scoping paper and workshop proceedings produced by GESAMP;

.2 Review and identify the best practices in modelling the physical and chemical (hence biological) behaviour of discharged tailings slurries or wastes, including shearing and upwelling of both the solids and soluble fractions. Determine if existing models are adequate or if further development is needed;

.3 Given that marine organisms normally used for toxicity testing are from the upper stratified layers of marine water, not the deep sea, review and identify the possibilities for standard sediment and aquatic toxicity tests that use species from deeper water, and preferably in situ;

.4 Identify low-cost methodologies and technologies for monitoring deep-sea environments before and after waste disposal activities;

.5 Consider what useful additional work might be done by the Working Group beyond that listed above (phase 2); and

.6 Produce a report on the above work.

**The expertise required by the Working Group includes:**

2 Marine scientists and engineers with expertise in marine ecology (in particular plankton ecology, macroalgae and benthos), fisheries, marine chemistry/geochemistry, biogeochemistry, and physical oceanography (including modelling);

**Work plan and provisional timeline:**

3 The working methods of the Working Group will be a mix of meetings and intersessional work/correspondence, including video/telephone conferencing where appropriate.

4 Provisional timeline for phase 1 (phase 2 to be agreed subject to availability of funding):

.1 Meeting in first quarter 2016;

[3] These will be updated using the final report of the GESAMP Workshop held in Peru (June 2015).

.2 Deliver interim report by end second quarter 2016;

.3 Deliver final report by end third/fourth quarter 2016 (preferably before the meeting of the LC/LP governing bodies);

.4 Peer review of the draft report by fourth quarter 2016; and

.5 Publication, dissemination and outreach.

**Administrative arrangements**

5 The following administrative arrangements are proposed:

**Sponsors**: IMO (Government of Canada), others (to be discussed at GESAMP 42).

**Budget and funding**: At least USD 50,000 secured (Government of Canada and IMO). Additional funding will be sought from Sponsoring Organizations and industry.

**WG Chairperson(s) and members**: Chairman tbd. Other members to be discussed at GESAMP 42.

**Technical Secretary**: IMO (Mr. Edward Kleverlaan)

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