**ABSTRACT**

The release of H2S (Hydrogen Sulphide) is a known risk in the dredging industry. It is a highly toxic and flammable gas (flammable range: 4.3-46%). Being heavier than air, it tends to accumulate at the bottom of poorly ventilated spaces. In addition, it is very pungent at first, but quickly deadens the sense of smell, so that it may easily go unnoticed and victims may be unaware of its presence until it is too late. H2S is highly poisonous with both long- and short-term effects similar to those of carbon monoxide. This article focuses on the H2S exposure which can occur during traditional dredging works and suggests some possible preventive measures such as recognising the H2S risk during the tender phase and taking measures to minimise it. As well, alerting crews to the risk and training them to prevent H2S risks are crucial.

**INTRODUCTION**

The first step is to understand Hydrogen Sulphide (H2S). The release of H2S is a known risk in the dredging industry. The gas typically accumulates in certain layers of the seabed, where organic material is decomposing in anaerobic (absence of oxygen) conditions. Known H2S sensitive areas are mangrove ecosystems in river estuaries, harbours with an extensive history of fishing activities and PASS (Potential Acidic Sulphate Soils).

**RECOGNISING POTENTIAL H2S RISKS**

Long-term, low-level exposure to Hydrogen Sulphide may result in fatigue, loss of appetite, headaches, irritability, poor memory and dizziness. Short-term, high-level exposure can induce immediate collapse, with loss of breathing and a high probability of death. The recognised effects on the human organism of increasing concentration of H2S are:

- 0.0047 ppm is the recognition threshold, the concentration at which 50% of humans can detect the characteristic odour of Hydrogen Sulphide, normally described as resembling “a rotten egg”.
- 5 ppm is the long-term exposure limit (8 hour time-weighted average).
- 10 ppm is the short-term exposure limit (15 min period).
- 10-20 ppm is the borderline concentration for eye irritation.
- 50 ppm is the acceptable maximum peak above the ceiling concentration for an 8 hour shift, with a maximum duration of 10 minutes.
- 50-100 ppm leads to eye damage.
- At 100-150 ppm the sense of smell disappears, often together with awareness of danger.
- 320-530 ppm leads to pulmonary oedema with the possibility of death.

Above: Dredging with a trailing suction hopper dredger in a direction perpendicular to the wind direction is one way to reduce the risk of H2S reaching the vessel’s interior. The yellow box seen here is an active carbon filter container.
dredger (TSHD) or backhoe dredger (BHD), the H2S release is caused by the vessel’s seabed disturbing activities,
- during works near offshore platforms (e.g., rock installation, cable laying, and such), H2S release is associated with the client’s offshore drilling activities.

This article focuses on the H2S exposure during the traditional dredging works and possible preventive measures.

**Characteristics of H2S**

H2S is slightly heavier than air (ρ = 1.36 kg/m³), so once released as a result of dredging activities it will descend to the lower parts of the vessel.

H2S has a moderate solubility in water. Depending on the water temperature, this varies from 7 g/kg at 0 °C to approximately 1.5 g/kg at 60 °C. This means between 7000 ppm to 1500 ppm H2S is dissolvable in one litre of water (Figure 1).

In the liquid phase, different forms can occur:
- H2S as the non-dissociated form (volatile);
- HS⁻ or S²⁻ as the two dissociated forms (non-volatile)

Neutral water has a pH value of 7 and at this value there is equilibrium of 50% H2S and 50% HS⁻. As from pH 5, 99% will be non-dissociated meaning that slightly acid to acid water will contain mainly volatile H2S (Figure 2).

**The stripping effect**

A volatile compound is characterised by its
RECOGNISING POTENTIAL H₂S RISKS ON DREDGING PROJECTS

When a project is being tendered for, the potential for H₂S presence has to be determined. Geographical and geologic information will already give a good indication for potential H₂S presence at the dredging location. Certain eco-systems are more likely to contain large quantities of H₂S piled up in particular layers of the geologic profile. Clay soils pose a higher potential for H₂S risks because its compact/dense structure allows for anaerobic decomposition. Dredging sand almost never releases large amounts of H₂S, as sand is very porous and thus allows gases to migrate.

If not already done on behalf of the client, soil samples can be analysed and scanned for H₂S presence. In the case that the presence of H₂S is indicated, then the project safety plan should define the technical and strategic measures to be implemented, e.g., detection systems and technical adaptions to the vessel. Emergency procedures should include responses to H₂S release and intoxication.
LIMITING H₂S RELEASE

Although there are a variety of theoretical options to limit the exposure to H₂S on a dredging vessel, the practical and feasible options are limited to a few engineering and procedural controls. These effective measures to limit a H₂S release are: covering the hopper; limiting the turbulence in the hopper; and diverting the airflow intakes on board.

Covering the hopper
Covering the hopper of a TSHD or SHD with a fabric restricts H₂S from reaching vulnerable areas. When the air above the water is saturated with H₂S gas, no more H₂S can be stripped from the dredged material into the air. In conjunction with covering the hopper, the air below the cover must be discharged at one side of the vessel. Therefore:
- the cover must have proper sized inlet vent(s) to get the hopper in an ‘under-pressure’ situation (inlet needs to allow a flow of at least 0.5 to 1 m/s);
- the mechanical fans to blow the H₂S containing air form below the cover, must be large enough to keep a sufficient under-pressure;
- mechanical fans and inlet vent(s) need to be of appropriate size; and
- special attention must be given when opening the bottom doors of the hopper as this creates a high under-pressure.

Emptying the hopper at a reduced speed and opening the hopper cover partially are crucial to the process.

Limiting turbulence in the hopper
Dissolved H₂S is released much faster as turbulence increases. Inside the hopper the main sources of turbulence are:
- dropping the dredged material from a high height in the hopper while loading (Figure 4) and
- discharging through the overflow system.

Both features cause agitation on the water surface, air-bubbles in the dredged material and an increasing contact surface between water/air. Dropping the dredged material from a lower height causes less oxygen to get absorbed and thus less stripping of H₂S. The effect of turbulence is further reduced if the discharge takes place below the water surface.

Taking into account the various types of dredging equipment, dredging by means of a backhoe or dipper dredger is considered as the best option to reduce H₂S release as the dredged material is not subjected to heavy turbulences and it can be kept in underwater or submerged conditions.

During loading of a TSHD or SHB, the use of a “deep load installation” strongly reduces the H₂S stripping effect. Lowering the discharge point to +/- 2 m from the bottom (preferably
Diverting the active carbon (A/C) intake(s)

With large flexible or hard ducts it is possible to divert the active carbon (A/C) intake to known places with much less H₂S (fore ship, monkey bridge, behind accommodations and such). Below mentioned measures can further reduce the risk to H₂S reaching the vessel’s interior:

- Dredging with a TSHD in a direction perpendicular to the wind direction
- Providing an A/C system with adjustable intake positions
- When filling up the hopper the A/C shall be switched to recirculation
- Keeping all exterior doors, hatches and windows closed during dredging.

Filtering the A/C intake(s)

There are various techniques available on the market to filter the accommodation air. Only a few however are feasible on board a dredging vessel. The most interesting technique is adsorption of H₂S by a suitable adsorbent, such as NaOH, KOH or K₂CO₃ impregnated active carbon. By utilising custom-made filters, the air can be purified prior to entering the accommodation (Figure 7).

MONITORING H₂S RELEASE

Having proper gas detection on board is essential to monitoring H₂S release. Measurements can be personal or on fixed places on board the vessel. All gas detection equipment has built-in alarms according to Time Weighted Average (TWA) and Short Term Exposure Level (STEL) values, defined by European legislation:

- TWA* = Time Weighted Average = long term exposure = 8h period = 5ppm
- STEL = Short Term Exposure Level = 15min period = 10ppm

*Other ways to express TWA are MAC (Maximum Acceptable Concentration) or TLV (Threshold Limit Value).
**Personal detectors**

To warn crew for H₂S, small single gas detectors such as type ToxiRAE III can be used. Single gas detectors are mostly non-pumped and do not have the capability to log the measured data. Multi-gas detectors such as type QRAE II can also be provided with an H₂S sensor and have an in-built pump, which makes it’s more suitable for outdoor measurements. The QRAE II does data-logging (Figure 8).

**Fixed detection**

A fixed detection system consists of multiple detectors which are strategically placed (in the hopper, A/C inlets, ER, ECR,...). These fixed detectors are connected to each other and are communicating with a central alarm box (often placed on the bridge). The connections can be either wireless or via fixed cabling. The advantage of wireless systems is that they can be easily relocated from one vessel to another (e.g., after a project is finished) but they have a limited battery life which is regarded as a disadvantage. H₂S Meshguard system kits are another system being used on various vessels.

Default the kit comes with 6 H₂S detectors, a router (signal seeker/enhancer) and an FMC2000 controller/alarm box. A Meshguard network can be established and expanded up to 26 detectors.

**Data logging**

When using devices that have data logging, it is possible to monitor certain locations on board for longer periods or even on a permanent basis. The portable QRAE II devices can be connected to a computer and by using the provided software and measured data can be consulted for interpretation. Via the internal modem, the wireless Meshguard H₂S sensors are sending their data to the central controller on the bridge, where it is stored on an SD memory card. Depending on the used detection mode, this can be either 24/7 or with a pre-set interval (default every ½ min) and/or whenever an alarm value is detected (Figures 9 and 10).

**CONCLUSION**

The release of H₂S (Hydrogen Sulphide) is a known risk in the dredging industry. It is a highly toxic and flammable gas and can cause debilitating health conditions. The exposure to H₂S risks in the dredging industry comes in two different forms, during traditional dredging works and as a result of the client’s offshore drilling activities. The situation addressed here was that caused by traditional dredging. In this case recognising the H₂S risk during the tender phase is essential and possible.

Knowing the risk early on allows the contractor to prepare a safe work environment and to include the costs for required measures such as detection systems in the price offer. Also, if an increased H₂S risk is determined, the initial dredging method can be substituted by a safer method (e.g., backhoe dredger) or engineering controls can be put in place, e.g., by installing a deep load box on a TSHD within a reasonable timeframe.

When a risk is possible, use of gas detection equipment on board to measure H₂S is crucial. It helps to monitor the effectiveness of the H₂S prevention measures and gives timely warning to the crew when these are failing. And last but not least: Every crewmember needs to be made aware of the H₂S risk and trained in preventive measures including the use of specific personal protective equipment (PPE).