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A COMMON SENSE APPROACH FOR H_2S RELEASE DURING DREDGING

ABSTRACT

The release of H_2S (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. H_2S is highly poisonous with both long- and short-term effects similar to those of carbon monoxide. This article focusses on the H_2S exposure which can occur during traditional dredging works and suggests some possible preventive measures such as recognising the H_2S risk during the tender phase and taking measures to minimise it. As well, alerting crews to the risk and training them to prevent H_2S risks are crucial.

INTRODUCTION

The first step is to understand Hydrogen Sulphide (H_2S). The release of H_2S 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 H_2S sensitive areas are mangrove ecosystems in river estuaries, harbours with an extensive history of fishing activities and PASS (Potential Acidic Sulphate Soils).

Hydrogen Sulphide 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. Although very pungent at first, it quickly deadens the sense of smell, so victims may be unaware of its presence until it is too late.

Hydrogen Sulphide is considered a broad-spectrum poison, which means that it can poison several different systems in the body, although the nervous system is most severely affected. The toxicity of H_2S is comparable with that of carbon monoxide.

RECOGNISING POTENTIAL H_2S 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 H_2S 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 (15min 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.

Note that the exposure to H_2S risks in the dredging industry comes in two different forms:

- during traditional dredging works, e.g., dredging by means of a cutter suction dredger (CSD), trailer suction hopper

Above: Dredging with a trailing suction hopper dredger in a direction perpendicular to the wind direction is one way to reduce the risk of H_2S reaching the vessel's interior. The yellow box seen here is an active carbon filter container.

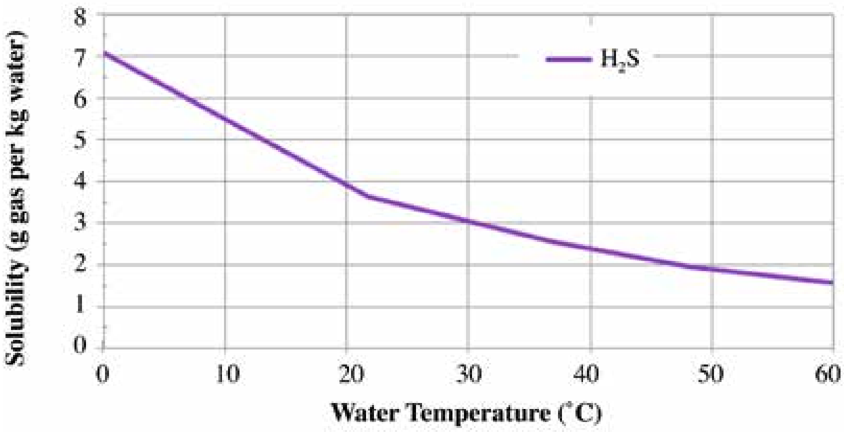

Figure 1. This graph shows the solvability of H_2S gas in water.

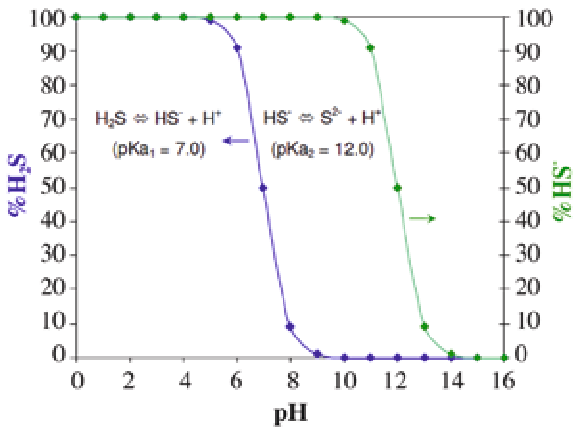

Figure 2. The graph above shows the shifting of the different Hydrogen Sulphide forms according to the pH.

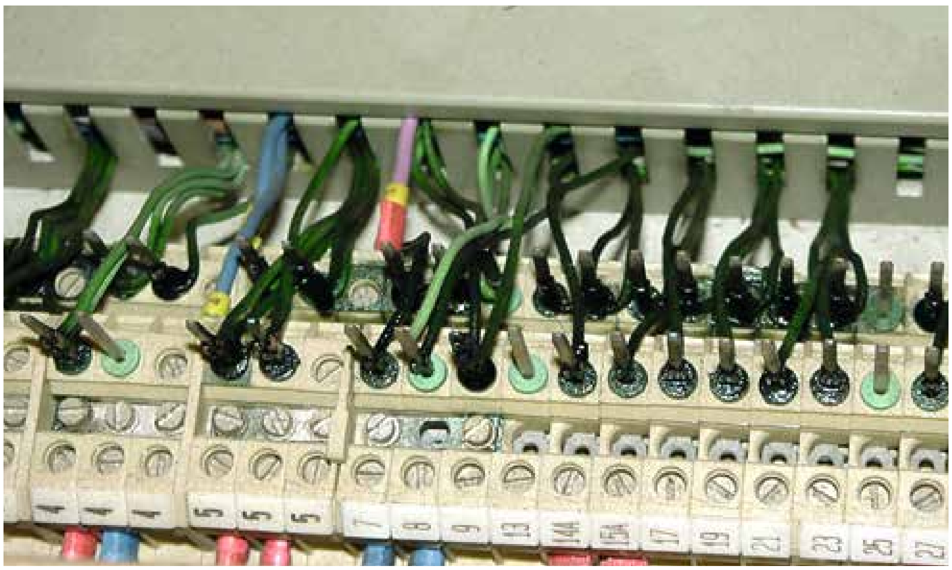

Figure 3. Electrical components that have been affected by H_2S on board the vessel.

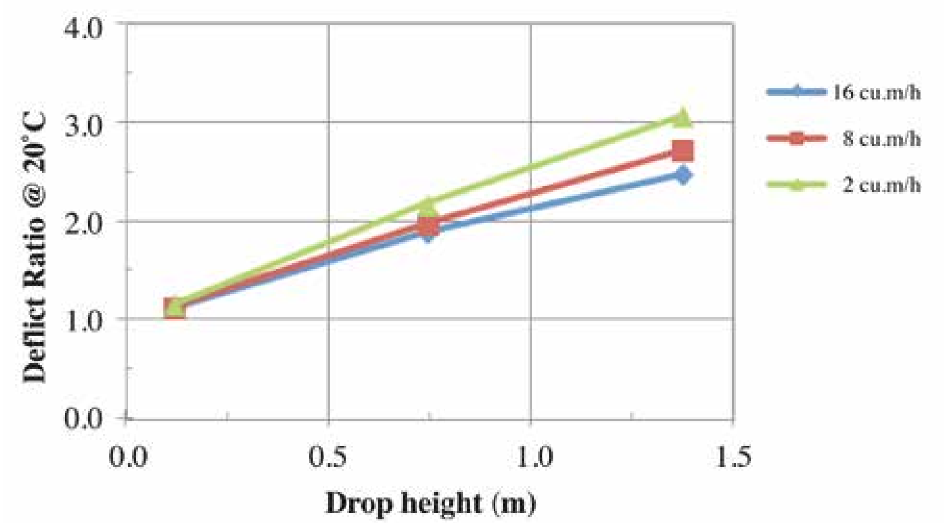

Figure 4. The graph shows the effect of drop height and oxygen absorption.

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), H_2S release is associated with the client's offshore drilling activities.

This article focusses on the H_2S exposure during the traditional dredging works and possible preventive measures.

Characteristics of H_2S

H_2S 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.

H_2S 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 H_2S is dissolvable in one litre of water (Figure 1).

In the liquid phase, different forms can occur:
- H_2S as the non-dissociated form (volatile);
- HS^- or S^{2-} as the two dissociated forms (non-volatile)

Neutral water has a pH value of 7 and at this value there is equilibrium of 50% H_2S and 50% HS^-. As from pH 5, 99% will be non-dissociated meaning that slightly acid to acid water will contain mainly volatile H_2S (Figure 2).

The stripping effect

A volatile compound is characterised by its

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Figure 5. Top photos, installed deep load systems; below, a newly fabricated extended discharge pipe for a TSHD.

Henry's law constant which is a criterion for describing air–water partitioning of solutes such as H_2S (known as the stripping effect). This value will reduce as the water temperature decreases, implying that colder water means less stripping, i.e., H_2S that stays dissolved in liquid condition.

Two other important factors have a significant impact on the stripping effect:

- The amount of H_2S in gaseous condition above the water surface (more H2S in the air results in a reduced stripping effect).
- Contact-surface: increasing turbulence in water holding H_2S means an enlarged contact-surface which results in more H_2S migrating towards the gaseous condition.

H_2S is a very reactive/corrosive gas. It affects metals like copper and brass, causing short-circuits on electrical components. This has been identified as the direct cause of fires on dredging vessels (Figure 3). *Limiting the turbulence inside the hopper (of a TSHD or SHD) is the keystone of the H_2S-preventing strategy on board dredging vessels.*

RECOGNISING POTENTIAL H_2S RISKS ON DREDGING PROJECTS

When a project is being tendered for, the potential for H_2S presence has to be determined. Geographical and geologic information will already give a good indication for potential H_2S presence at the dredging location. Certain eco-systems are more likely to contain large quantities of H_2S piled up in particular layers of the geologic profile. Clay soils pose a higher potential for H_2S risks because its compact/dense structure allows for anaerobic decomposition. Dredging sand almost never releases large amounts of H_2S, 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 H_2S presence. In the case that the presence of H_2S 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 H_2S release and intoxication.

Figure 6. Various ways of diverting the accommodation active carbon (A/C) intake.

LIMITING H_2S RELEASE

Although there are a variety of theoretical options to limit the exposure to H_2S on a dredging vessel, the practical and feasible options are limited to a few engineering and procedural controls. These effective measures to limit a H_2S 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 H_2S from reaching vulnerable areas. When the air above the water is saturated with H_2S gas, no more H_2S 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 H_2S 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 H_2S 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 H_2S. 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 H_2S 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 H_2S stripping effect. Lowering the discharge point to +/- 2 m from the bottom (preferably

Figure 7. Details of custom-made active carbon filters (above) and their installation on a TSHD (left).

below water surface from the start) at the centre of the hopper is most effective. Keeping a certain space between the bottom of the hopper and the discharge point, prevents the pipe from getting clogged-up by solid materials.

Also limiting the discharge velocity prevents H_2S stripping. This can be achieved by using a larger pipe diameter and/or making certain adaptations to the end discharge point of the pipe.

The pictures in Figure 5 illustrate adaptations made on board of TSHDs. They range from simple modifications of the discharge pipe (extending + metal diagonal insert) to placement of a complete "deep load installation".

AVOIDING THE ENTRANCE OF H_2S GAS INTO THE INTERIOR SPACES OF THE VESSEL

Through the air intakes (e.g., air supply for the air-condition system) or simply through door and hatch openings, H_2S gas can easily migrate from the exterior towards the inside of the vessel. Two proven methods to avoid H_2S being sucked into the vessel's interior spaces through air intakes are diverting air intakes to locations where H_2S is not present and filtering of the A/C intake by means of active carbon filters. In addition to these measures, all other openings such as doors and hatches shall be kept closed during dredging.

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 H_2S (fore ship, monkey bridge, behind accommodations and such). Below mentioned measures can further reduce the risk to H_2S 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.

Figure 8. The multi-gas detector QRAE II.

Note that based on this understanding, the standard position of accommodation A/C intake on new vessels is located at the side or front of the vessel instead of above the hopper (Figure 6).

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 H_2S by a suitable adsorbent, such as NaOH, KOH or K_2CO_3 impregnated active carbon. By utilising custom-made filters, the air can be purified prior to entering the accommodation (Figure 7).

MONITORING H_2S RELEASE

Having proper gas detection on board is essential to monitoring H_2S 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 H_2S, 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 H_2S 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. H_2S Meshguard system kits are another system being used on various vessels.

Default the kit comes with 6 H_2S detectors, a router (signal seeker/enhancer) and an FMC2000 controller/alarm box. A Meshguard network can be established and expanded up to 26 detectors.

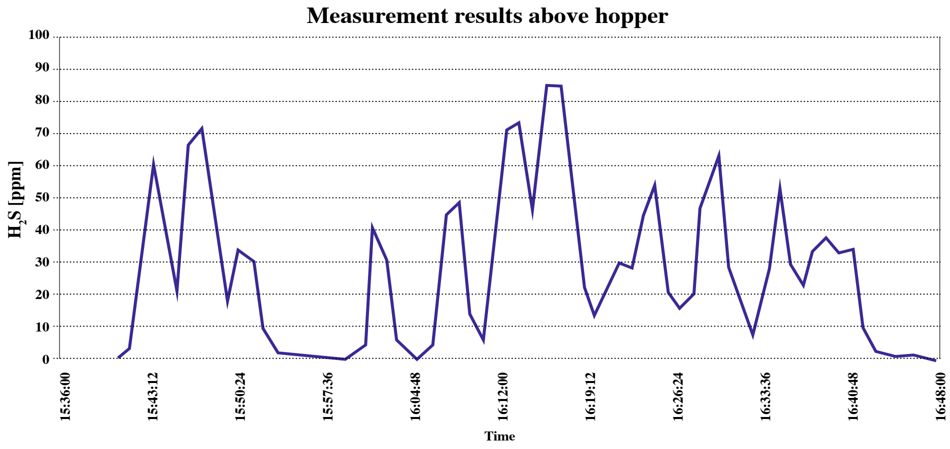

Figure 9. A measurement graph from on board a hopper dredger. The typical work rhythm can be identified: high peaks (going up to 100 ppm) during filling hopper and the obvious decrease of H_2S measured during sailing.

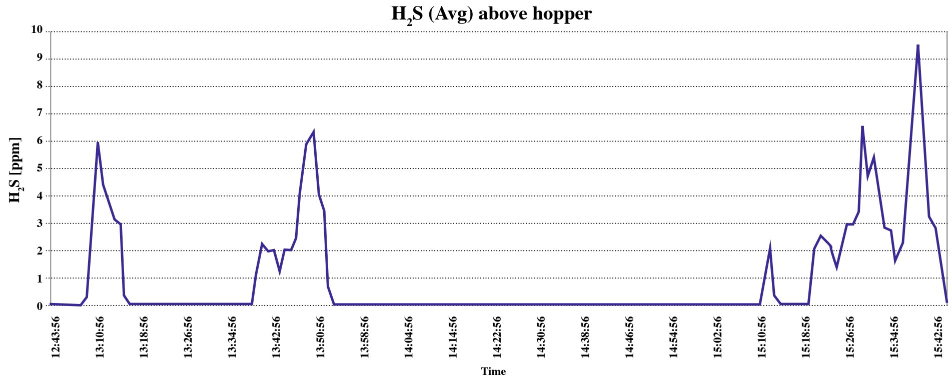

Figure 10. Reading on board a split barge, during the loading process with a cutter dredger. Again, the work rhythm can be identified (minor H_2S peaks during loading barge).

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 H_2S 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 H_2S (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 H_2S 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 H_2S 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 H_2S 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 H_2S is crucial. It helps to monitor the effectiveness of the H_2S 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 H_2S risk and trained in preventive measures including the use of specific personal protective equipment (PPE).