Director General

Maisons-Alfort, 15 July 2010

OPINION

of the French Agency for Food, Environmental and Occupational Health Safety (ANSES)

Concerning recommendations for the prevention of health risks to neighbouring populations, walkers and workers caused by green algae

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ANSES's public health mission involves ensuring environmental, occupational and food safety as well as assessing the potential health risks they may entail.

It provides the competent authorities with the necessary information concerning these risks as well as the requisite expertise and technical support for drafting legislative and statutory provisions and implementing risk management strategies (Article L.1313-1 of the French Public Health Code).

Background

Every summer for over 30 years, coastlines in France and particularly Brittany have been affected by "green tides". These masses of green algae washed up on the beaches—apart from being unsightly and having a negative impact on tourism—release significant amounts of gas when they decay, particularly hydrogen sulfide (H_2S), which may cause unpleasant odours and health problems for local residents and anyone walking in the vicinity. To overcome this pollution, the algae are removed from some beaches, exposing workers in particular to these gases.

These green tides are caused by an excess of nitrates due to human activity and the particular shape of bays which enable algae to proliferate more readily.

In an attempt to stem this phenomenon, the French government drew up a five-year plan in February 2010 to fight green algae. The goal is to ensure that the algae are brought under control and to implement measures by 2010-2011 in order to reduce nitrate emissions by at least 30 to 40% by 2015 in the eight "green algae" bays identified in the Master plan for water management and development (SDAGE) for the Loire-Bretagne watershed. The strategic plan to be applied on three levels simultaneously, will involve:

- implementing preventive measures to stop nitrogen emissions finishing up on the coasts (through improved treatment of effluents and waste water generated by industry, agriculture and local authorities, land stewardship, changes in agricultural practices);
- improving knowledge of the phenomenon and managing risks;
- restoring polluted environments through more effective cleaning and treatment techniques for washed- up algae.

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On the basis of this plan, on 23 February 2010 the Ministries of Ecology, Labour and Health requested that ANSES:

1. identify the complete range of gases emitted by the algae and the corresponding risks to the health of exposed populations according to levels of concentration;
2. propose measurement and dosimetry protocols for sites affected by massive algae deposits;
3. review the scientific literature for potential health consequences that might be associated with chronic exposure to low hydrogen sulfide concentrations;
4. draw up specific recommendations for workers exposed while collecting and/or treating green algae;
5. draw up national public health recommendations for the general public and shoreline residents exposed to green algae emissions, regarding potential toxicity thresholds and olfactory nuisance.

The solicited request follows a number of studies and projects already underway, particularly in Brittany, where informative documents for the public and prevention guidelines for professionals working on algae collection, transportation and treatment have been written and distributed.

Presentation of the Issue

Given the urgency and in order to provide information on the health risks for the current holiday season, priority was given to drawing up guidelines for preventive measures for workers and the public. Consequently this Opinion provides initial answers to questions 4 and 5 of the solicited request.

Given the currently available data and the urgent need for public health measures, the experts focused on acute exposure situations, especially since it seems that the primary concern at this time is to prevent acute risks due to hydrogen sulfide exposure.

Answers to the other questions in the request will be provided at a later date as this will require more data which is not yet available. A better understanding of occupational exposure may lead to changes to the recommendations given in this Opinion.

Organisation of Expert Assessment

The emergency procedure for dealing with health related requests was used by ANSES due to time constraints. In this type of situation, recourse to an expert committee (CES) is optional and the expert assessment is performed by an *ad hoc* working group. ANSES thus created the "Green Algae" working group (WG) for the expert assessment. The areas of expertise required were health risk assessment, occupational health, environmental health, metrology, toxicology and chemistry. The WG was made up of:

- Mr. Alain BAERT – Hospital practitioner (Centre hospitalier universitaire de Rennes [Rennes University Hospital Unit]) – Area of expertise: Toxicology.
- Ms. Isabelle LOPEZ – Hospital practitioner (Centre hospitalier universitaire de Rennes [Rennes University Hospital Unit]) – Area of expertise: Occupational medicine.
- Mr. Daniel PICART – Retired (Former Teacher-researcher at the Université de Bretagne occidentale [University of Western Brittany]) – Area of expertise: Chemistry.
- Mr. Nicolas RISLER – Chief engineer (Laboratoire central de la préfecture de police [Police Headquarters Central Laboratory]) – Area of expertise: Gas metrology, accidentology.
- Ms. Renée RUNIGO-MAGIS – Safety engineer (Assistance publique – hôpitaux de Paris [AP-HP]) – Area of expertise: Occupational safety.
- Ms. Isabelle ZDANEVITCH – Research engineer (Institut National de l'Environnement industriel et des Risques [National institute for industrial environment and risk]) – Areas of expertise: Physical chemistry, metrology, waste management.

The expert assessment was conducted in accordance with standard NF X 50-110 "Quality in expertise activities - General requirements of competence for an expertise activity (May 2003)" to ensure compliance with the following points: competence, independence, transparency, traceability.

The conclusions of this expert assessment were thus reached by a group of experts with complementary skills.

The information and recommendation documents previously drawn up in Brittany were considered to be the main basis for the committee's work. They have moreover already been distributed to the local authorities, employers and public health organisations working in the algae treatment sector.

The items in this Opinion are intended to complement these documents. They provide a further explanation of some of the techniques to be implemented in order to prevent the main risks identified, according to the current state of knowledge. They are not intended to replace existing documents and regulations, which remain applicable.

Facts about Green Algae

Not all green algae found along shorelines - which grows more or less abundantly depending on the year - cause green tides.

Two species of algae are usually involved:

- *Ulva armoricana* is found mainly on the northern coastline of Brittany,
- *Ulva rotundata* is only found in southern Brittany.

Other green algae species, such as the less proliferative *Cladophura laetiniens*, are also found.

Green tides are the result of accumulated green algae caused by significant nitrogen runoff, a wide, flat intertidal zone and the hydrodynamic confinement of coastal waters.

H_2S emissions are particularly high when sulfate-rich plants decay, which is the case with all sulfated sugar-rich Ulva (ulvans), but not red or brown algae which emit considerably less H_2S during decomposition. When fresh, algae emit very little gas.

In general, proliferation reaches its height in mid-July but depending on environmental conditions (sunshine, rainfall, etc.) and the tides, growth may be observed until mid-October.

When tide coefficients are low, Ulva deposited at the top of the beach are not taken back by the sea.

It is easy to spot algae in a state of advanced decomposition. When exposed to the sun, the surface of the accumulated algae dries, forming a whitish crust. Very little light penetrates this crust which means that photosynthesis is interrupted, thus creating fermentation conditions which are first aerobic then anaerobic.

Figure 1: Freshly beached green algae, Côtes d'Armor (source: Ouest France)

Figure 2: White crust on the surface of a decomposing algae deposit (source: Air Breizh)

Sulfate-reducing microorganisms, which are highly abundant in seawater, use the sulfates found in algae and in the marine environment as a source of oxygen, which causes the formation of hydrogen sulfide (H_2S). A similar process results in the formation of ammonia (NH_3) from nitrates.

Ulva are highly light-dependent, which means that in cloudy weather, turbid water or shade due to the algal proliferation itself, their growth is limited.

Facts about Hydrogen Sulfide (H_2S)

Hydrogen sulfide is a highly toxic gas, slightly heavier than air, which explains the greater risk in confined areas. In an unconfined atmosphere, such as on the coast, it is assumed that hydrogen sulfide behaves like air and the fact that it is heavier than air therefore does not aggravate exposure.

Its characteristic rotten-egg smell may be detected at levels as low as 0.2 to 0.3 ppm (0.28 to 0.42 mg/m^3); it is obvious at 20 to 30 ppm (28 to 42 mg/m^3), but at levels close to 100 ppm (140 mg/m^3) the sense of smell is anaesthetised.

H_2S is a respiratory tract irritant and neurotoxic by asphyxia.

Hydrogen sulfide penetrates the body *via* the pulmonary route. The gas passes into the blood where it is found in several different forms.

H_2S is lipophilic and spreads quickly and readily in body tissues. Its main toxic mode of action is direct inhibition by binding to the iron in cytochrome oxidase aa3, a key enzyme in mitochondrial function. This causes a blockage in the mitochondrial electron transport chain and reduced oxygen use, resulting in anaerobic metabolism and the production of lactic acid. Tissues with high oxygen requirements such as the brain or heart are especially sensitive to metabolic interruption by hydrogen sulfide.

In addition, gaseous hydrogen sulfide first irritates the ocular mucosa, due to H_2S gas dissolving in the humid environment of the surface epithelia, closely followed by respiratory tract irritation.

Once metabolised, H_2S is eliminated in urine (90%) mainly in the form of sulfates, thiosulfates and sulfides.

The severity of intoxication depends more on the concentration level than on the exposure duration.

There are also hyperacute forms of intoxication, involving sudden loss of consciousness ("knock-downs") and cardiac arrest. These forms have been described for concentrations of around 1,000 ppm (1,400 mg/m^3). A similar concentration was measured *in situ* by INERIS on a mound of green algae decomposing on the Saint-Michel-en-Grève beach in 2009. With levels beginning at 500 ppm (700 mg/m^3), and several minutes of exposure, neurological signs are constant and may include coma; cardiovascular problems may also occur (hypotension, tachycardia, cardiac arrhythmia, myocardial ischemia).

From 200 ppm (280 mg/m^3), prolonged exposure—over 10 minutes or so—leads to neurological symptoms such as headaches, dizziness, nystagmus, disorientation, impaired coordination, nausea, vomiting and severe asthaenia.

Moderate concentrations, between 50 and 200 ppm (70 to 280 mg/m^3), initially cause irritation of the ocular and respiratory mucosa with symptoms including photophobia, conjunctivitis, rhinitis, hoarseness, coughing, and chest pain. Prolonged exposure (several hours) at these concentrations may cause corneal lesions (keratitis) and a risk of permanent eye damage.

The link between keratitis ("gas eye" or "spinner's eye") and exposure to hydrogen sulfide gas alone (less than 100 ppm, or 140 mg/m^3) has been rejected in favour of a hypothesis of co-exposure to several irritating gases (viscose rayon industry).

Four to 16% of cases typically include delayed lesional pulmonary oedema starting at 250 ppm (350 mg/m^3).

At a concentration of 100 ppm (140 mg/m^3) for 30 minutes, even without the aid of respiratory protection, workers can reach a safe place without any hindrance of their ability to do so and with no risk of irreversible damage to health.

At low exposure levels (10 ppm, or 14 mg/m^3), neuropsychic, cardiac and respiratory effects are undetectable. While several researchers have studied the effects of this concentration during physical exercise (50% of max VO_2), no problems have been observed.[1]

For chronic exposure to levels near the maximum limits set for workers, effects on health are controversial. Irritation to the respiratory tract and some neuropsychic disorders have sometimes been reported, but the available studies do not allow definitive conclusions to be drawn.

Occupational exposure limits (OELs) for hydrogen sulfide can be found in the occupational regulations. OELs are minimum objectives, not to be exceeded, and worker exposure to air pollution must be as low as possible. These OELs are concentration values at which no extended organic or functional effects, either reversible or irreversible, have been established for exposed workers.

Weighted average over 8 hrs		Short term (15 min)	
ppm	mg/m^3	ppm	mg/m^3
5	7	10	14

Recommendations for Walkers

French shorelines are unevenly affected by green tides, and it is likely that it will not be possible to clean up all beaches affected by algae. Protective measures must therefore be taken for these beaches.

Recommendations

- The presence of algae deposits on such beaches must be indicated by signage warning walkers of the hazard and persuading them not to enter these danger zones.
- In addition, permanent local markers must be installed to indicate algae accumulation that cannot be cleaned up. The marked area should include a security perimeter of at least 30 metres (estimate based on available data).
- Worksites must be clearly marked to keep the public away (see section on protective and security measure specifications for installing the markers).

Recommendations for Workers

1. General organisation of the green algae treatment system

The governmental plan recommends that "... in order to avoid the risk of fermentation and toxic gas emission, the removal of green algae must be intensified and the spreading of fresh (non-stabilized) algae must be limited and strictly monitored. Secure treatment facilities must be established as soon as possible." The sequence of steps for the algae treatment system must

[1]INRS, 2009, Hydrogen sulfide toxicology data sheet, FT 32; INERIS, 2009: Hydrogen sulfide. Toxicology and environmental data sheet for chemical substances; Lauwerys R., 2007, Toxicologie industrielle et intoxications professionnelles, Masson, 5th ed., 1276 p.

therefore be organised coherently. To date, there are two principal methods of eliminating green algae: spreading and treatment.

CEVA (the *Centre d'études et de valorisation des algues*) found high hydrogen sulfide concentrations (over 100 ppm, and as high as 500 ppm) in 5-day old deposits of green algae. Algae should therefore be dealt with in a shorter lapse of time.

Recommendations

- **Algae must be collected while fresh**, that is within 24 hours, and no more than 36 hours after it washes ashore, provided that treatment does take place within 48-hours of collection. Only by collecting fresh algae can major protection constraints be dispensed with during collection.
- The collection, transportation and management of algae in treatment centres must take place as quickly as possible; less than 48 hours should elapse between algae collection and the start of treatment. Intermediate storage should be avoided as much as possible.
- It is essential to ensure traceability throughout collection, transportation and treatment. In the event of intermediate storage, the date and time of collection must be indicated and recorded for each bin.

2. General Regulatory Obligations

Employers are subject to mandatory regulations designed to protect workers. The safety regulations for each profession remain applicable. Only those obligations that are relevant to the particular case of workers in the green algae treatment sector are reviewed in this document. With a view to prevention, they are integrated into ANSES's recommendations so that they apply equally to all participants in the sector, whether local authorities, agro-business, companies with employees or independent workers.

Recommendations

- In any situation that could potentially lead to exposure to decomposing green algae, all possible measures must be taken to ensure that no worker works alone where he/she cannot be quickly rescued in case of accident.[2] These measures include alarm systems (technical devices, remote monitoring by an observer located outside the danger zone able to intervene only with specialised equipment) and measures for rescue operations.
- To limit exposure to hydrogen sulfide during collection of decomposing green algae, all beaches must be equipped with a wind sock to indicate wind direction.[3]
- All workers must be informed in advance of the hazards related to their activity, related risks, prevention and protective measures to implement and action to be taken in case of incidents or accidents occurring.
- Rescue teams that might be called upon to intervene in case of accident must also be trained and an intervention plan drawn up.
- A "prevention plan" must be established in writing between the supervising contractor and the company for any "external" operation entrusted to a private company.[4]
- In the event that several companies are working in the same area, the manager of the user company (supervising contractor) must coordinate the preventive measures for risks associated with any overlap in the companies' work. This coordination may be delegated to a worker.[5]

[2] Art. R. 4512-13 of the French Labour Code
[3] INRS, 2005, Risk of poisoning posed by hydrogen sulfide, Recommendation R 420
[4] Art. R. 4511-1 to R. 4514-10 of the French Labour Code
[5] Art. R. 4511-9 of the French Labour Code

3. Motorised Collection

Motorised algae collection has the advantage of enabling collection of large quantities at a time, and of isolating workers from toxic gas emissions from decomposing algae. Different types of machines are used for algae collection and handling.

Recommendations

- If possible, algae collection and handling must be done using closed-cab, air-conditioned machines with effective H_2S filters. This equipment must be duly maintained and inspected according to the manufacturer's instructions.
- Regardless of the type of machine used, drivers must have individual H_2S detectors near their respiratory tracts. Drivers do not wear respiratory protection devices all the time. When the H_2S detector exceeds the alarm level of 10 ppm (or 14 mg/m^3), the operator must put on a full-face respirator mask with filter cartridge, available in the driver's compartment. He/she must then drive the vehicle out of the polluted zone. The operator may only return to his/her task after airing out the cab, if this is possible, or moving to a zone deemed to be free of decaying algae deposits, and only if the detector indicates that the level has dropped below the alarm level. However, with a closed, air-conditioned and air-filtered cab, it is possible that an alert from the detector is indicating filter saturation which then requires replacement as indicated by the supplier.

4. Beach Collection on Foot

On mudflats or in rocky areas that are inaccessible to mechanical equipment, it may only be possible to collect algae manually.

Recommendations

- Wearing a gas detector is mandatory throughout manual collection operations.[6] It must be switched on at a distance of at least 30 metres from the danger zone.
- To collect fresh algae, the operator is not required to constantly wear a respirator. If the H_2S detector exceeds the alarm level of 10 ppm (or 14 mg/m^3), the operator must put on a full-face respirator mask with filter cartridge attached to the belt, and leave the polluted zone. The operator may only return to his/her task if equipped for collecting decomposing algae as described below.
- When collecting algae with a whitish crust, workers on foot are likely to be highly exposed to H_2S, particularly when their tools break through the crust. Therefore the use of a self-contained respirator mask is mandatory when collecting green algae. Where possible, these situations are to be avoided.

5. Storage

Algae, once collected, are generally placed in bins that are carried to treatment centres by lorries according to an irregular schedule. Bins may be temporarily stored above the beach for varying periods of time. Algae storage increases the risk associated with decomposing green algae.

Recommendations

- Storage is to be avoided.
- However, if storage is unavoidable, it must be done in an open bin, not a closed one, in order to prevent gas accumulation that would cause a sudden release of H_2S when opened.

[6] Art. R. 4321-4 of the French Labour Code

- Storage traceability is imperative. The date and time of collection must be recorded for each bin, and this information must be available until the bins have arrived and been moved to treatment platforms (chip or barcode electronic devices may be considered for bins.)

6. Transportation – Dumping

The critical operations during transportation are loading and above all dumping. The following precautions must be taken.

Recommendations

- For loading and unloading operations, safety measures must be specified in writing in a "security protocol" document.[7]
- In addition, operators loading and unloading algae must be proficient in the use of hand signals applicable to manoeuvres using machines.[8]
- During dumping operations, workers operating within 30 metres of the bin and the pile of unloaded algae must use a rapid response H_2S detector. A full face mask filter cartridge respirator must also be made available.
- Offloaded algae must be treated immediately and thoroughly mixed with a structuring agent in order to reduce the likelihood of H_2S forming.

7. Spreading

The procedure being formalised in the Lannion region consists in spreading the algae onto fields within 24 hours of collection, and burying it within 48 hours. These deadlines will help limit the odour impact of the decomposing algae.

Recommendations

- "Bottom-of-the-field" algae storage is not recommended.

8. Treatment

There are several different procedures which may be applied successively:

- Stabilisation to preserve algae for future use, to even out amounts to be treated by the facilities throughout the year;
- Drying, to reduce the amount of water in the algae, thus reducing the volume (and therefore the weight) of the algae transported and handled, and to limit biodegradation for which a humid environment is necessary;
- Composting, which in the presence of air decays the organic matter in the fermentable waste, eliminating pathogens, reducing mass through evaporation and CO_2 emissions and transforming organic matter into humus. This product can then be used as an organic soil amendment.

Recommendations

- It is the treatment centre operator's responsibility to comply with regulations for classified environmental protection facilities.

[7] This document features the items in the Ministerial Order of 26 April 1996 (Arts. R.4515-1 to R. 4515-11 of the French Labour Code) applicable to loading and unloading operations performed by a third-party company.

[8] Council Directive 92/58/EEC of 24 June 1992, on the minimum requirements for the provision of safety and/or health signs at work.

Specifications for protective and safety measures against H_2S exposure

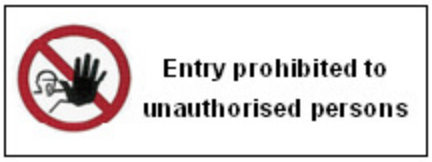
The priority of these specifications is to protect people from the risk of acute hydrogen sulfide poisoning.

1. Danger Zone Signage

Danger zone signage is a fundamental principle for protecting individuals who are exposed to a potential risk.

Recommendations

- When collection operations are underway, signs must be set up around danger zones to prohibit access. These must be circular in shape with a red surround and an easy-to-understand black pictogram on a white background.[9] For example:



or

- Where appropriate, the danger zone must be cordoned off. Authorised marker types are:[9]

or

- Only operators responsible for algae collection and transportation shall be authorised to enter these restricted areas. Gas detectors and personal protective equipment are mandatory for access to danger zones.

Mask

Gloves

Protective clothing

2. Gas detectors

A gas detector is a device which indicates the concentration of a gas in the atmosphere of an area or zone, in real time. There are multifunction devices which detect toxic gases as well as flammable gases and oxygen levels.

The main parameters to consider in choosing a device, as well as ANSES recommendations, are shown in the table below. It is generally best to refer to manufacturer recommendations for use, calibration and maintenance.

[9] Ministerial Order of 4 November 1993 on health and safety signs at work, OJ of 17 December 1993

Parameter	**Recommendations**
Concentration or alert signal: Some devices may only give a signal when gas levels in the air exceed the threshold.	▶ Devices must give a number indication in addition to the signal; all others are to be avoided.
Types of gas measured: Devices may be monogas or multigas.	▶ The main acute risk is H_2S. Given the current knowledge about exposure levels to other gases, the systematic use of an H_2S monogas detector should be sufficient to ensure personnel safety under satisfactory working conditions.
Concentration range	▶ The concentration range for H_2S should be between 0 and 100 ppm.
Range of substances found: H_2S levels may be affected by the presence of ammonia and dimethyl sulfide, which are also emitted by putrefying green algae.	▶ Any interference indicated by the device manufacturer must be checked for any over- or underestimation it may cause.
Response time: The alarm trip time reflects the interval between the time the detector is subjected to a variation in concentration and the time the alarms actually go on. Sensor response time varies greatly from one device to another, from 20 seconds to more than a minute.[10]	▶ The exposure scenario of most concern is the H_2S peak emissions when the algae mass is disturbed. Short reaction times are therefore necessary, no more than 20 seconds.
Ease of use: Detectors may be portable or fixed. Generally, the weight and bulk of the device increase with the number of substances the device must measure.	▶ Monogas detectors are small and light and may be worn on the collar or breast pocket; multigas detectors are heavier and worn on the belt.
Maintenance: Maintenance consists in checking that the device works and, if not, repairing it.	▶ Follow the manufacturer's instructions. In compliance with the INERIS study, detectors must be inspected upon delivery. Then, for normal use (8 hours per day), a periodic check—at least once a month—is recommended. In addition, proper functioning of the detector must be checked periodically after several uses, use over a long period (less than a month) or if exposed to H_2S for long periods (several hours per day for several days).
Memory: The device's memory may store data for a period of operation exceeding one day, and provide averages and comparisons of these averages to OELs. Memory devices are useful in assessing actual worker exposure over the duration of their shift.	▶ Individual memory devices are recommended as they monitor worker exposure to hydrogen sulfide.

[10] INERIS report INERIS-DRC-10-113094-05297A

Recommendations

- In applying general prevention principles, when the risk of exposure to H_2S is unavoidable, (1st principle), the risk must be assessed (2nd principle). With regard to H_2S exposure, the risk must be assessed by providing workers with suitable detectors (with the characteristics outlined above).
- Workers must be trained to use gas detectors.
- Each company must have access to a facility for checking proper detector function and in particular H_2S response (presence of an H_2S mix canister in the maintenance shop with an individual trained to use the device, or access to a nearby authorised facility in the field; alternatively, devices may be returned to the manufacturer or distributor for inspection.)

3. Respirators

Personal protection equipment (PPE) is defined in Article R. 4311-08 of the French Labour Code. It is defined as "devices or equipment worn by an individual for protection against potential health and safety risks." The execution, choice and use of PPE must adhere to a specific prevention procedure (which is the responsibility of the site manager). This PPE must be suitable for the risk involved as well as the working conditions. The French Labour Code devotes several sub-sections to chemical risk prevention and Ministerial Orders, Circulars and recommendations specify the means to do it.

Source: INRS

- Full face mask filter cartridge respirator

For hydrogen sulfide exposure through the collection, transportation and treatment of green algae, the appropriate respiratory protection is a full face mask with a filter cartridge respirator[11].

Recommendations

- The filter type to use with green algae is the A2B2E2K2 P3.
- A full face mask is recommended. Powered air purifying respirators (PAPR) are also effective using the same type of filter cartridge.
- The filters must comply with standards NF EN 143 (particle filter) and NF EN 14387 (gas filters and combination filters).
- Filter storage conditions and expiry dates must be checked at least once a year.[12]
- Personnel must be provided with information on the conditions of use of these devices and trained in their use (depending on the type of respirator: conditions of use, set-up, leak control and impact of beards, etc.)[13]
- Between uses, the device and filter must be kept in an airtight container.

[11] INRS, 2003, Respirators, choice and use, ED 780
[12] Ministerial Order of 19 March 1993 setting out the list of personal protection equipment which must undergo periodic inspections as outlined in Article R. 233-42-2 of the French Labour Code, OJ of 28 March 1993.
[13] Articles R. 4323-104 to R. 4323-106 of the French Labour Code.

Source : INRS

- Self-contained respiratory protection device (SCBA)

The use of an SCBA is required during manual green algae collection operations. The SCBA consists of a full face mask and air or oxygen tanks independent of the ambient air. This equipment does not require a filter cartridge. The breathable air supplied must comply with standard NF EN 12021 and be as pure as possible. Filters may be needed to keep the oil mist level in the air below 0.5 mg/m^3. The minimum compressed air flow is 120 L/min. For heavy physical labour, the air flow may be above 200 L/min. The pressure of the compressed air must remain below 10 bars.
The SCBA may be open circuit, with exhaled air being released back into the atmosphere, or closed circuit, with used air being recycled and reused by the device.[14]

This equipment is effective in atmospheres polluted by substances at concentrations over 2,000 times the maximum limit, or 28,000 mg/m^3 of H_2S.

Recommendations

- As working conditions with this equipment are particularly demanding, it should be used only when absolutely necessary.
- Due to its self-contained oxygen supply, training and practice in equipment usage and regular inspections are extremely important in order to avoid creating additional risks.
- Where appropriate, the employer determines the duration of the work shift and conditions under which the equipment is made available and used, taking into account the physical effort required to perform the task and the discomfort when wearing this equipment.
- These devices must be checked for proper working order before each use and must be inspected at least once a year.[12]
- The equipment must be maintained according to the manufacturer's recommendations.
- When it is necessary to use this equipment, the occupational physician must consider each individual worker's ability to wear this equipment.

4. Eye Protection Equipment

Eye irritation due to H_2S exposure has been reported at 50 ppm (70 mg/m^3). Eye protection to prevent irritation is therefore necessary. As the full face mask with filter cartridge and the SCBA also protect the eyes, the specific use of eye protection equipment only concerns work shifts which do not require respirators.

The choice of eye protection goggles must take into account the use of any corrective lenses worn by the operator (in accordance with standard EN 166).

[14] INRS, 2002, Respirators, choice and use, ED 780

Recommendations

- During work shifts where the use of a respirator is not necessary, operators must use eye protection equipment.
- Only airtight safety goggles provide a barrier between gaseous H_2S and ocular mucosa.

Protection from exposure through contact with algae broth

Instructions are given here as to the choice of protective equipment to avoid hand and eye contact with the mixture of sea water, particles and compounds that could result from green algae decay.

1. Skin Protection Equipment

There appear to be no studies on the mixture of sea water, particles and compounds that could result from algae decay. It is possible that substances in algae broth could pose a risk of skin irritation. When handling algae, this phenomenon could be exacerbated by the abrasive nature of the particles in suspension and the use of tools that can injure skin.

Therefore these operations require protection against chemical and mechanical hazards.

- Work clothing

Clothing and boots suitable for use with chemical hazards must be worn by operators on foot in order to avoid skin contact. The discomfort of wearing waterproof overalls must be taken into account, as the physical effort required inevitably raises body temperature and causes water loss.

- Gloves

In keeping with the current state of knowledge, gloves must be Category II "intermediate risk" for mechanical and chemical hazards.

Recommendations

- Gloves must be worn in all situations where the operator may come into contact with decomposing algae.
- Gloves must be waterproof and guarantee protection from chemical products (in accordance with standard EN 374).
- They must ensure mechanical resistance specifically by resisting cuts and tears (in accordance with standard EN 388).

- Gloves suitable for this type of exposure are made of nitrile or PVC.

2. Eye Protection Equipment

During the handling of fresh algae, eye and face protection from algae broth splashes is necessary.

Recommendations

- During work phases where there is no risk of H_2S exposure, operators must wear a face shield.

Drawn up in five original copies,

Director General

Marc MORTUREUX