

# HIRA

the Dive Business Guide  
to Safe Diving Operations








## Contents

- 1** An introduction to the DAN Hazard Identification and Risk Assessment Programme
- 3** Caring for your people
- 5** Caring for your facilities
- 7** Caring for your business





# An introduction to the hazard identification & risk assessment programme

The DAN-SA Hazard Identification and Risk Assessment programme promotes a culture of safety at diving businesses. Here is an overview of the programme.



After being summoned to stitch up yet another finger mangled by the ladder hinges on a local diving boat, one of our colleagues, a diving doctor, notably said “That is it! I have had it with these sliced fingers!” The words echoed with frustration and a plea for intervention. And they were heeded, as DAN responded. The result of that response is the Hazard Identification and Risk Assessment (HIRA) Programme which is able to focus the attention of all parties invested in the diving industry on reducing avoidable and repeated accidents.

The idea of hazard identification and risk assessment is not new. These are well-established principles for most industries. The challenge, though, was not to simply create a new programme, but to establish a proactive culture of diving safety. This required buy-in and implementation; in a word: “participation”. So, how did we achieve this?

DAN has been working on improving the safety and efficacy of recompression treatment facilities around the world since 1999 with the DAN Recompression Chamber Assistance and Partnership Programme (RCAPP). The need for having access to reliable recompression facilities is obvious. However, following the appeal from our finger-stitching colleague, DAN decided to expand the chamber safety initiative toward diving operations. The question, however, was how to start.

The first step was to establish collaborative relationships with diving operators based on mutual trust. So, with this in mind, DAN began to actively acknowledge those diving operators who were willing to partner on issues of diving safety by demonstrating their compliance with established industry norms, including staff readiness, first aid training, and emergency equipment and protocols. Then, as the interactive dialogue between DAN and the respective diving operators evolved, the HIRA Programme was formally introduced in 2008, following the same core principles employed in RCAPP.

Francois Burman, the CEO of DAN Southern Africa (DAN-SA), provides an overview of the HIRA Programme, followed by a discussion on the specific operating aspects of the typical diving business and its interaction with clients – recreational scuba divers. The goal is to make a real difference to diving safety through the creation and promotion of a culture of safety at all scuba diving schools, charters and operations around the world. That is what DAN is all about.



## Programme overview

The primary mission of DAN-SA is to offer assistance to injured recreational scuba divers. An important secondary mission is to prevent diving injuries. As part of a global campaign to reduce injuries and fatalities related to recreational scuba diving, DAN-SA intends to fulfil its vision that every dive be accident and injury free by identifying and mitigating risks associated with diving operations.

The primordial prevention of injuries or losses implies the active prevention of accidents from happening, which in turn requires a programme that generates awareness, establishes control and ultimately mitigates health and safety risks.

So, how does one create, promote and then build such a preventative programme? After much deliberation and engagement with our diving Industry Partners, the following overall objectives were formulated:

- To provide risk and safety awareness education to all participants.
- To offer guidance on risk mitigation and control, based on actual operational aspects of a business.

- To initiate and then grow participation by all diving service providers.
- To monitor accidents and incidents so that we can continually assess the status of progress toward our vision of diving safety.
- Achieving these objectives has required inclusion and co-operation at all levels, primarily through the empowerment of facilities to understand and then accept their responsibilities toward safety.

Before describing the process, it is important to state, for the record, that DAN-SA does not represent any regulators, nor does it serve a statutory role. As such, DAN-SA is not the “scuba police”. We believe that the best way to encourage a diving safety culture is by role-modelling and through positive engagement with all the parties involved. Secondly, DAN-SA will only engage in this process if specifically invited to do so by a diving business. This is crucial for complete buy-in and full engagement on a voluntary basis.

## Programme introduction

The extensive, 16-year experience with the RCAPP has clearly shown that there is great value in providing a structured, methodical and consistent process. The DAN Risk Assessment Guide is available in multiple languages and used around the diving world and has been instrumental in this regard.

This same concept is now extended to diving businesses by means of a structured, documented process – the DAN HIRA Guide. This guide offers the means for realistic assessment of actual operational hazards and safety solutions over the whole spectrum of diving business activities from the welcome to the water. The focus is on identifying the real and present risks, not theoretical or merely superficial ones. We refer to this as identifying the potential hazards, followed by a risk assessment.

DAN-SA also backs this process up by providing practical measurement tools and resources to quantify the risks. In addition to obvious elements, like compressed air quality testing, DAN-SA also includes several less familiar concerns, such as the assessment of harmful environmental noise exposure and ensuring adequate lighting measurements are used for safety purposes.

After identifying the potential hazards, risk mitigation follows. This implies that the source of the risk should be clearly identified and isolated, so that it can then be addressed in a meaningful way.

## “ The DAN-SA HIRA Guide is available in multiple languages.

When approaching any risk associated with an interface between man and machine, there is a tiered approach. By this we mean that the options for risk mitigation begin by trying to eliminate them at the source, using some form of technical or engineering control, like a barrier. If this is not possible or feasible, then operational methods are employed, such as providing instruction through policies or procedures to prevent any hazardous interaction with the risk. An example of such policies or procedures is teaching people how to use the ladder. If neither of these are possible, then physical protection is required, like supplying hearing protection to compressor workers.

As with any programme, monitoring or measurement is required to confirm its effectiveness. This also allows feedback on the success of the risk assessment and mitigation steps over a period of time and for a wider range of operational situations.

For the purpose of establishing a lasting safety culture, however, personal on-site discussion with diving business staff is required and all parties need to appreciate the risks and agree to the mitigation and monitoring strategies.



# Programme tools

In terms of the actual implementation of a risk mitigation strategy, there are two primary concepts that need to be established.

Firstly, we need to determine the key or critical control points, namely the main sources of the hazards, so that we can be sure to address the root causes and plan for routine safety assessments and interventions to ensure optimal risk reduction.

Secondly, not all risks are of the same importance or magnitude. As such, a risk measurement system helps to focus the priorities of a business and to provide some degree of assurance that resources and efforts are directed appropriately. The assessment tool used is encapsulated in an accepted definition of the term “risk”: The probability that the exposure to a hazard will lead to negative consequences.

By establishing these two primary concepts we can consider all the potential hazards and then determine the chances or likelihood that people or equipment could actually be exposed to these hazards and whether the potential harm would be severe (namely unacceptable) or not. This turns the theory into practice: It allows us to identify the real issues over those that can be dealt with at a later stage or even disregarded.

The concepts of probability, exposure and consequence can all be quantified using a relatively easy-to-use, one-to-five scale. The actual risk can thus be calculated by multiplying these three scores by each other and by comparing the total score with a typical risk score table.

RISK SCORE	RISK LEVEL	DESCRIPTION
>100	1	Extreme (danger)
50-100	2	Very high (stop usage)
20-50	3	High (urgent attention)
5-20	4	Medium (attention needed)
<5	5	Low (acceptable risk)

# Existing regulatory documents

Statutory and industry-regulating documents vary depending on national-, local- and industry-specific requirements. It is, however, essential that all parties know which of these apply to them and what their relevant responsibilities are.

- The following documents apply to the South African recreational diving industry and there will be equivalents of these in all countries:
- Occupational Health and Safety (OHS) Act of 1994, together with the applicable regulations such as the Noise, Driven Machinery, Electrical Installations, Environmental Safety, General Safety, General Machinery and Hazardous Chemical Substances Regulations;
  - Compensation for Occupational Injuries and Diseases Act (COIDA);
  - National Conservation Act;
  - Employment Equity Act;
  - Labour Relations Act;
  - South African Maritime Safety Authority (SAMSA) directives which are applicable to boating and diving operations; and
  - South African National Standards (SANS) 10019 (compressed gas cylinders) and SANS 532 (gas quality).

There are many additional documents which provide guidance, instruction and recommendations on gas cylinder valves, cylinder markings, medical gas cylinders, equipment testing and cylinder filling requirements, to name a few.

# How do diving businesses indicate their interest in participating in the HIRA programme?

The simple answer is just ask! Upon receiving the initial invitation, DAN-SA sends an experienced team of assessors to the diving business site to take a detailed look at their diving operation. This should include actual day-to-day activities, covering the full scope of the business and may include:

- Staff health and safety;
- Client health and safety;
- Staff training and certification;
- Training pool area;
- Training room;
- Diving retail shop;
- Diving boat operations;
- Live-aboards;
- Compressor and cylinder filling area;
- Equipment storage area;
- Small instrument workshop;
- Vehicle safety;
- Travel and health advice for clients; and
- Recompression chamber dives.

“ This DAN HIRA Guide offers the means for realistic assessment of actual operational hazards.


Then, after the observation period, the team discusses their findings and impressions with the business management representatives. The DAN-SA team will describe the assessed risks together with the possible mitigation recommendations and possible ongoing monitoring or measurement techniques.

To capture the outcome of the assessment, a detailed, customised report is generated by the team and shared with the particular diving business and the key members of staff.

The final report is an invaluable document: It not only provides a baseline of the current safety status, but also offers a roadmap toward ongoing safety improvements according to importance. Specific recommendations are offered where existing mitigation strategies are lacking or incomplete. It is then up to the business management to review, accept and apply the recommendations.

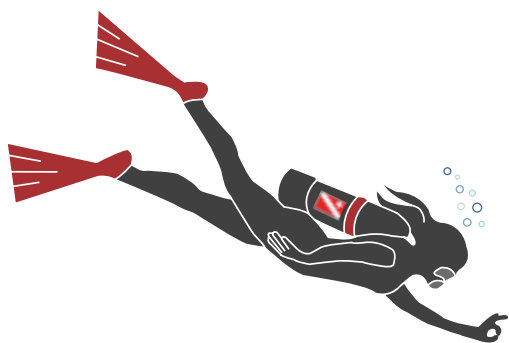
Established industry standards are followed as the general guideline, but the HIRA Programme is about something far more than rote compliance to a norm. The ultimate intention is for the *DAN HIRA Guide* to be the signature of a safety-aware diving operation.





# Caring for your people

Learn about the importance of caring for  
your staff members and clients.







The HIRA Programme intends to change the way in which diving businesses approach safety. The idea is to develop a culture of safety within diving businesses, rather than to simply provide an added service to fulfil a necessary obligation. We would like this to become an intrinsic value that diving customers will look out for specifically when choosing with whom they dive.

In a world where the customer is the top priority, can a business truly afford to invest in the safety of its own people without compromising the service to its clients? Then again, can a client truly come first if the employees and hired hands are at risk? How can a business apply the principles of the HIRA process in a way that serves both the clients and its own people?

A core objective of the HIRA Programme is caring for staff members. We will use familiar concepts such as identifying the hazards, assessing the real risks, mitigating these risks and then monitoring the outcomes to provide an objective means to assess if the processes are effective. Once a foundational culture of safety is established amongst the staff, caring for the clients (the divers) becomes a natural extension of the culture, rather than simply a job.

## Staff member health and safety

In many parts of the world, diving businesses employ freelance, contracted or migrant staff members. As a result, the period of employment is usually relatively short, and it may not be obvious or even seem sensible to make any special investment in the health of these staff members. Moreover, some of the most pristine and spectacular dive sites are located in the developing countries where statutory staff health and safety obligations are rarely enforced on the employer. This may create the impression that these obligations do not even exist. However, a quick glance at the website for the International Labour Organisation (ILO) at [www.ilo.org](http://www.ilo.org) tells a very different story.

Almost all countries have accepted the obligations of the ILO constitution. This in turn implies that any person who could in any way be judged as deriving a benefit from the service of others would fall under the suitable provisions for employment even in the loosest sense of this word. They, therefore, need to be protected against any form of unnecessary risk, abuse or mistreatment whilst under the responsibility of an employer.

It also clearly shows that whilst many business owners might claim that there are no such definitions, rules and responsibilities, these do actually exist even though they are perhaps not always easy to find. Most countries uphold the principle that the ignorance of the law is no excuse for breaking it. Therefore, attempting to justify negligence or the abuse of staff by claiming ignorance would be a very shaky excuse. It is true that the specifics may not be clear, but the onus remains on the beneficiary of the services, namely the employer, to find, understand and meet the legal requirements.

But, we are not here to discuss legal obligations. Rather, we want to understand the actual risks to the business and then figure out how best to mitigate them.

### Staff member health and safety requirements

In most countries, there will be an existing set of requirements that needs to be complied with. These requirements are put in place to protect the health and welfare of any person who is employed in any fashion by another. It is thus imperative that you accept this requirement as a reality, take advice on what is required, and then to display the relevant legislation or make it available and known to all the staff members.

Remember that laws are there to protect both the employee and the business. If you follow the rules and something still happens, you have a good chance of mitigating responsibility. This is surely better than always being at the sharp edge of the sword.

### Establishing a health and safety policy

It is important to establish a clear, effective and appropriate health and safety policy within the business. Being proactive sends a very clear message to your staff members, and through them, to your clients.

The question of what such a policy should contain is dependent on the size, nature and scope of your activities, but the risks you need to cover here include, as a minimum:

- Clearly spelling out the hazards that are inherent to the workplace;
- Ensuring that employees are covered by a suitable form of compensation insurance as well as diving insurance;
- Appointing a staff representative who is responsible for considering and speaking-up on safety matters;
- Establishing a staff medical surveillance programme; and
- Providing suitable protection against all identified workplace hazards.

To tie this all together, we need to illustrate the utmost importance of monitoring health and safety policies. It is not sufficient to simply tell your staff members about a hazard (sun) and to then simply provide them with some protection (sunscreen), as you are legally obligated to ensure that such a work-request is implemented. So, yes, this would actually mean writing up a member of staff who fails to heed your health and safety warnings.

“ The idea is to develop a culture of safety within diving businesses, rather than to simply provide an added service to fulfil a necessary obligation.

# Staff member training and certification

Any client would expect a business' diving instructors and guides to be professionals, thus properly trained and competent. This requires a continuous staff training and evaluation system to ensure that all the staff members, especially in high staff-turnover situations, are familiar with all the aspects of the advertised diving excursions, and especially with any foreseeable emergency situations.

Of course there is more to it than this, as training for new staff members should not only focus on the diving aspects, but also on all other safety procedures, such as equipment handling and maintenance, legislative requirements and the necessary first responder skills.

So, what do we look for when assessing staff member training and certification? A diving business requires a formal staff training process where training logs and certifications are maintained, where a competent staff training person is either available at the business location, or at least dedicated to that business, and where all the required first responder skills are current and on record. We therefore advocate that, as a minimum, a diving business should be able to:

- Provide first aid on site;
- Provide basic life support on site;
- Provide high-concentration oxygen on site;<sup>1</sup>
- Perform a neurological examination on site; and
- Preferably have the ability to utilise an automated external defibrillator (AED), especially for remote dive sites which are far from suitable resuscitation facilities.

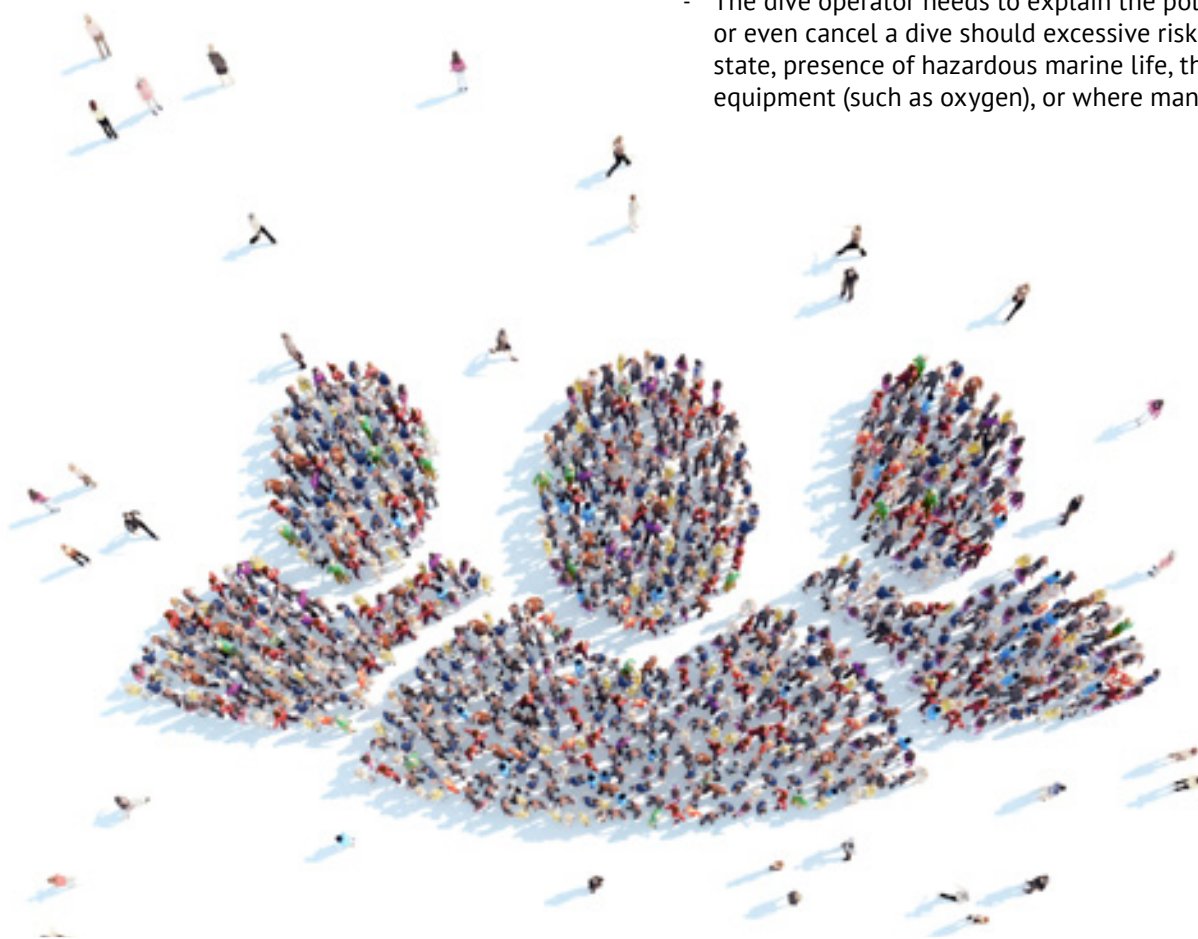
# Client health and safety

With a sound staff caring system in place, a business is better equipped and primed to provide at least the same level of care to its clients.

The most obvious aspects of client health and safety would include ensuring that all clients are certified divers, fit to dive and that any medical- or health-related issues are communicated to the diving guides prior to any diving excursion. This might even include special needs such as assistance for handicapped scuba divers. Clients also face several other health challenges, some of which are not directly related to diving. These health challenges may require that suitable travel advisory information is provided during their initial travel planning stage.

Thus, the dive operator needs to address the following client risks in advance:

- The client needs to complete a comprehensive, formalised and confidential health questionnaire that focuses on any significant reasons why he or she might need further medical clearance. The dive operator then needs to ensure that only fit-to-dive clients are taken to the dive site.
- The dive operator needs to check the availability and validity of the client's appropriate dive medical insurance, together with the relevant contact details in the event of a medical or safety emergency.
- The dive operator needs to record the client's emergency contact details.
- The client needs to sign a suitable indemnity form to protect the diving business from unnecessary or undeserved claims for losses or injury.
- The dive operator needs to enjoy adequate indemnity insurance that is in place for both professional and public liability.
- The dive operator needs to ensure that clients are certified divers and have some form of a dive logging system in place. This will aid the decision as to whether a diver needs a refresher course based on when their last dive was done.
- The dive operator needs to brief clients as to the restricted areas both at the diving business site, such as compressor rooms, as well as at the dive sites or on-board the dive boat. Note that suitable signs are also needed to indicate the restricted areas.
- The dive operator needs to explain the policy that is in place to restrict or even cancel a dive should excessive risks arise due to the weather, sea state, presence of hazardous marine life, the non-availability of safety equipment (such as oxygen), or where mandated by the local authorities.



## FOOTNOTES:

1. The recommended minimum required oxygen available at a dive site should allow high concentrations (> 80%) of oxygen to be provided to at least two injured divers for the time it would take to transport them from the dive site to where they may receive further oxygen or formal medical attention. As a rough estimate, 1 kg of oxygen per diver per hour would cover most oxygen delivery situations.



Please remember that post-dive checks of both staff members and clients are essential. An appropriate level of vigilance should be maintained for any signs and symptoms of decompression illness (DCI) or any sudden or significant changes in a person's health status, such as extreme fatigue, fever or malaise.

All clients should be briefed with the following post-dive restrictions:

- Divers must not be exposed to altitude (flying or driving over mountains) for 18 to 24 hours after completing a dive.<sup>2</sup>
- Divers must keep well hydrated (approximately 200 ml every 30 minutes or so).
- Divers must not take part in any strenuous exercise for at least four hours after no-decompression dives and more than eight hours for decompression dives.
- Divers must keep the after-hours and emergency numbers on hand in order to contact the business or local medical facility, respectively, if they experience any signs or symptoms of DCI or any significant changes in their health status.<sup>3</sup>

## Travel and health advice

The final part of this puzzle is to provide clients with good advice well in advance about travelling to your destination. It inspires confidence and may avoid many difficulties or disappointments. There is quite a list of prompts that can be provided depending on your location, your situation and the health and associated risks of the region. By alerting your clients to plan carefully, it shows that you take health and safety issues seriously. It also avoids having to turn down individuals if they have disqualifying medical conditions and it assures that everybody knows that you have their safety and best interests at heart.

Below is a list of considerations to note of before travelling to your destination. These aspects are all based on the risks that might apply, together with the suitable risk mitigation steps:

- Health and safety: This list could be long and may include advisories on recommended vaccinations, the risk of malaria or other relevant endemic diseases (like yellow fever) and the need for adequate travel insurance.
- Associated health advice: Here we want to advise clients to pack appropriate medication; offer precautionary information about certain substances (for example the information about relevant drug law enforcement issues and the possible need for proof of a medical prescription for any controlled substances), sunscreens and insect repellents; help clients to understand the standard of local healthcare facilities and the availability of recompression facilities; and to be mindful of general and environmental concerns, such as the availability of drinking water, local foods, disease transmission and general hygiene issues.
- Costs and general information: Although perhaps more a matter of convenience, let your clients know about the local currency, the availability of ATMs, the acceptability of credit cards versus cash, tipping practices, electricity supply and suitable electricity adapters, and also the fast-becoming essential issue of Internet or Wi-Fi access.
- Visas, documents and customs formalities: Let your clients know well in advance what documentation they need to be able to visit a specific country, to drive, to show local and returning health authorities, and to clear their diving gear through customs. Also notify your clients about any baggage restrictions as some island-hopping flights have limited space and weight allowances.
- Getting around locally: Inform your clients about the preferred and reliable local transport services, and which are less so; any considerations that might affect their travel insurance, such as unchartered flights or unlicensed transport services; and whether self-driving is recommended or not. Also, if relevant, you may want to make your clients aware of local annoyances such as petty theft and to be aware of personal security issues.

- Weather: Perhaps all is fair and equal underwater, but there are definitely better times to travel weather-wise and therefore suitable clothing, rain protection and other appropriate attire certainly makes atmospheric malaise more manageable.
- History and culture: Finally, some advice on what to wear to ensure that clients do not end up in awkward or perhaps even dangerous situations. Relay any cultural sensitivities or behaviour that is considered particularly unacceptable or offensive and even what languages are spoken or understood.


“Divers must not take part in any strenuous exercise for at least four hours after no-decompression dives.

## In conclusion

All successful businesses know that the true heart of a venture lies in its people. Managing or at least acknowledging the workplace stresses ensures that your clients arrive prepared. It also shows everyone that you have thought through the issues that might present themselves. This will not only reduce the likelihood of incidents or accidents, but it will also ensure that everybody feels truly cared for. Even if things do go wrong, being prepared does much to inspire confidence, reduce panic and mitigate any negative impact on the business. Indeed, there is no better advertisement for a sustainable diving business than to demonstrate a culture of safety awareness.

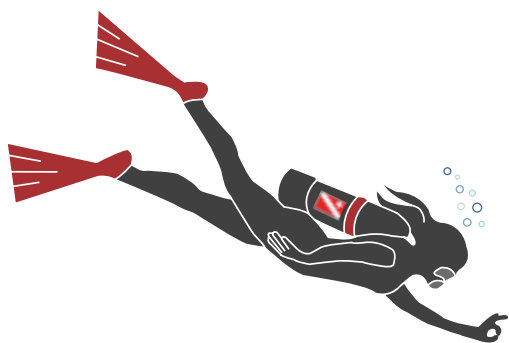
### FOOTNOTES:

2. The South African Undersea and Hyperbaric Medical Association (SAUHMA), in collaboration with DAN, published recommended intervals after single, repetitive and decompression diving. Please consult the following source for specific recommendations: <https://goo.gl/Rwb6YT>
3. DAN does not recommend primary transport to a recompression facility, as it may not be open or adequately staffed at all hours and it may not have the necessary diagnostic and medical support capabilities to manage an unstable diving casualty, especially if the problem is not diving-related. Local conditions may prescribe a different sequence of assessment and care, but the general recommendation is to first obtain proper medical assessment and stabilisation before referral to a recompression facility.



## Caring for your facilities

With proper care for your facilities, clients are assured that your business is serious about safety.







In building a working environment that supports productivity and reduces fatigue, a business should pay close attention to ergonomics, space utilisation, suitable flooring and house-keeping in order to keep the flow of activities running smoothly. Adequate lighting, good ventilation and air-conditioning to maintain comfortable environmental temperatures (which is rarely the natural state of popular diving areas) will further reduce workspace fatigue and the chances of staff members making mistakes.

Nobody wants to live in fear of disaster, but if a diving business is prepared and equipped, it can deal with emergencies in a way that reassures its staff members, as well as its clients, while mitigating the situation. Easy access to all the necessary emergency numbers and service providers, as well as the actual means to reach them, is absolutely essential. In the case of a disaster, it is important to provide for emergency exits, fire and security control measures, warning alarms and sufficient first aid supplies.

These are all logical and practical measures and none of them are entirely new to us. However, by systematically checking which everything which is needed is in place, a diving business will maintain both its facilities as well as the skills to manage it. It will also highlight likely concerns and enhance the business's safety profile from the moment the guests enter the premises.

## The compressor

With few exceptions, all scuba diving operations will have their own compressors or ready access to one. Some may have cylinders that are filled off-site, but most are likely to cater for rental and filling in-house. Whatever the option, there are specific safety issues associated with the handling of compressed gases and the associated equipment.

### The compressed gas area

A diving operation needs to pay particular attention to the appropriate occupational health and safety requirements regarding the active area where gas is compressed and stored. The working machinery needs to be clearly demarcated and access should be restricted to authorised staff only. All personnel should wear protective shoes, eye protection and hearing protection (a noisy area means that staff members' hearing needs to be regularly screened too). Possible fire hazards and the means to deal with these emergencies need identification, equipment and specially-trained staff members.

Pay particular attention to the appropriate occupational health and safety requirements regarding the active area where gas is compressed and stored.

### Compressors, boosters and the gas-handling plant

The most important risk-mitigating factor in dealing with potentially dangerous equipment is having competent, well-trained staff members. All compressed-gas operators must be properly trained and declared competent to work in this area. This is one of those areas where formal appointments and clear job descriptions are essential. Machine guards, supporting rails, properly-connected electrical junctions and safe electrical supplies are the common inspection areas for visiting authorities. The gas compressing plant needs a rigorous inspection and maintenance programme, checking that monitoring instruments function, intakes are out of harm's way, exhaust gases are routed away from intakes or occupied areas, checklists are followed and maintenance schedules and logs are duly kept up to date. No gas compressing machinery should be left unattended or at least unmonitored while switched on. All waste materials and fluids need proper storage and disposal procedures.

A diving business requires three things to serve its clients, namely the right water environment, the right people and the right facilities. Individual diving businesses use different combinations of services and infrastructure to establish themselves. It would, however, be rather unusual to see any diving business without at least a basic shop, a compressor, a store room and a service or repair station. Given these common features, we can easily apply the same core HIRA process to ensure the safety of all of these components – including the economic viability and financial security of the entire business. There may be some unique exposures to consider, but in most cases the HIRA principles can be extrapolated to any situation.

This process can be applied in such a way that not only assures a safe facility, but also assures clients that the business is serious about safety. Apart from the clients' interests, however, diving businesses also represent a large financial and human investment, which is usually built up over many years and therefore this needs to be protected from inadvertent and careless losses as well.

So, let us see how to identify the relevant hazards, assess the real risks, mitigate these risks and then monitor the efforts to ensure that the facilities are safe, effective and protected. We offer a more thorough framework that is typical for the average diving facility below.

## The shop

Every business needs a front-of-house or an attractive way to greet its clients. The type and nature will vary with the location and whether diving equipment is sold or rented out. To achieve this, a complement of effective, suitably-educated, empowered and equipped staff members is needed. They should be versant in the relevant spoken languages and able to provide information about dive sites, local surroundings and all the areas of concern that visitors should heed rather than discover by accident.

An effective means to train new staff members, retain existing staff members and demonstrate the required duty of care is to keep a procedure manual, which contains all the standard practices of the business on record. This includes the standard response to questions and situations, all the essential information on dealing with emergencies and possible adverse situations, and documentation demonstrating compliance with the national and local regulations and by-laws.

## Scuba diving and storage cylinders

A diving operation often has a combination of owned, rented or guest property cylinders. Therefore, additional checks need to be put in place. The industry cornerstone of safety is to ensure that all cylinders handled by the business are “in-date”, visually acceptable, and where they are part of the business’s assets, formally registered on an inventory with their current and future visual and hydrostatic test dates recorded.

A compressed gas cylinder contains an enormous amount of stored energy and must be handled, stored and mounted using the appropriate equipment. A technique that can be used to prevent mixing with the wrong gases is to ensure that client cylinders are emptied prior to being filled. Topping up a cylinder without knowing what is in the cylinder may prove fatal.

### Air quality programme

The only way to provide safe breathing air is by paying attention to where the air comes from and how it is handled. Diving operators should start with the intake and ensure that the area is clearly demarcated, warning signs are put in place and public access is restricted.

Carbon monoxide is not only a contaminant gas (for example, an intake problem) as it can also be produced by an overheating compressor (for example, a maintenance problem). A strictly-monitored air-filtering programme should be adhered to, using high-quality filter media which is suitable for the actual environment. The air quality system should be documented with regular testing (typically monthly), and monitoring of trends and reviews to confirm that the standards are met. Diving operators must take note of any client complaints, and they must be vigilant to subtle changes in the air-compressing and quality system.

### Oxygen-enriched gases

Oxygen-enriched gases require even more diligence due to the increased fire hazards. All enriched gases, especially pure oxygen, need a dedicated set of filling and handling instructions, procedures and even tools. Contamination by hydrocarbons, flammable liquids and vapours, and even certain lubricants must be avoided.

## The store room

Most dive operators have encountered a storage area with piles of unused goods that form a perilous mountain, threatening to tumble down and hurt someone, or at least cause some damage. There are a few basic rules to follow for an equipment and diving gear store room:

- The lighting should be adequate for the application.
- Ventilation is important in combating rot and the build-up of harmful fumes.
- It is safer to move about and it is easier to retrieve things in a proper storage space with secure, higher-placed items.
- All diving gear and items that degrade when exposed to ultraviolet rays should be kept away from direct sunlight.
- Hygiene and infection control are essential for all equipment and gear that is to be handled by staff members or clients.
- Stores contain burnable materials, especially when things are left lying around for long periods of time. Ensure that fire-fighting measures and equipment are in place and keep clearly flammable materials in separate, controlled areas.

## The service station

Most diving operations will have some type of workshop for maintenance and repairs. This might range from some kind of essential repair station to a fully-equipped instrument workshop and service centre. The critical function here is to ensure that the business is not derailed due to basic equipment that is not fit for service, as the essential spare parts are not available, or due to sudden breakages or losses. In some cases, servicing is outsourced if the necessary skills are not available in-house. However, we all at least acknowledge the fact that life-supporting breathing apparatus needs to be serviced and be able to function effectively and safely. Cleaning, servicing and repair work introduce their own hazards with respect to chemicals, aerosols, sharp and heavy items, as well as longer-term health issues. Basic maintenance services, even simple regular

inspection and identification of faults in need of servicing or repair, is an essential aspect of ensuring diving safety. The training of staff members on the required diving equipment maintenance, ranging from safety inspections through to full service and repair, should be a minimum requirement. The access to maintenance areas should be limited to prevent theft and tampering, and to prevent unauthorised persons from exposure to sharp or heavy tools, dangerous chemicals and other associated hazards.

“ All divers should be suitably positioned on the boat, preferably close to their equipment as well as to their dive buddy. a major part of engaging with clients.

All workshop facilities require good lighting, adequate ventilation and ergonomically-suitable working facilities. Protective equipment and clothing should be available to workshop or maintenance staff members. The chemical, electrical and mechanical hazards associated with these activities should be clearly identified and suitable notifications should be placed for staff to see. In addition, appropriate and well-maintained first aid kits should be located within easy reach of all maintenance and service activities.


## In conclusion

Even though diving businesses vary geographically and in terms of size, complexity, clientele, scope of services and even age, all these facilities share certain integral and essential elements to permit dive training and diving activities.

Many divers now choose their future diving destinations online. Word-of-mouth recommendations also form a major part of engaging with clients, therefore visible commitments to quality and safety form a major part of the final decision. You will more likely succeed in attracting clients if your operation is well-organised and managed to the point where a quick glance shows that diving safety begins behind the scenes in the business too. The HIRA Programme offers the opportunity to provide that.

Scuba diving might be a recreational activity, but the way of making this available to the participants, and not only where financial remuneration is concerned, is an area that is covered by occupational health and safety regulations. Ultimately, whether selling a certification, a diving excursion, equipment or even an equipment service, there are always facilities involved. These facilities need to be functional and safe. By paying attention to the essential behind-the-scenes areas critical to safety, the inadvertent disruption of a business becomes less likely and success becomes more probable.





# Caring for your business

With proper care of your business, your clients will be assured that you are serious about safety.



We have covered the essential resources for running a sustainable, safe and reliable business. The last element to consider is the business of diving, be it training, tourism, or open- or closed-water diving.

Having ensured that we have the right people and the right facilities, we now need to ensure that we head for the right water. There are four key elements to consider in preparing for and launching into any water, namely the training room, the training pool, transportation to the dive site (by land, air or water), and finally transfers at and from the dive site, including those from shore or from a dive boat before, during or after diving. Once again we apply the HIRA process to ensure the safety of all participants, including supervisors and instructors, students, skippers and support staff members.

Whenever we leave the familiar and controlled environment of our own facilities, we need to consider the potential hazards related to those elements which are less predictable and usually outside of our control, namely transportation to and from dive sites via roads (including traffic), launch sites and the open water itself. As always, the key lies in first identifying the relevant hazards (by knowing the environments well enough to recognise them), secondly by assessing the real risks (by determining the likelihood of an occurrence and the potential consequences), thirdly by mitigating these risks (through planning and fore-thought) and finally by monitoring our efforts (to ensure that we keep our people and our assets safe).

## The training room

A diving operation is responsible for the safety of its employees and that of the public, including customers and students; thus there are always occupational issues to consider.

The training room is a controlled environment where staff members and students should stay safe and out of harm's way, but it can present significant risks to a diving operation.

Diving centres are often located in or near popular diving areas, which are usually situated in tropical areas with high heat and humidity. Keeping students comfortable and alert enough to absorb and apply the training they receive to ensure their safety in the water means that a diving operation needs to put the following basic safety plans in place:

- Provide adequate lighting, specifically around the standard level of 200 lux.
- Provide adequate ventilation. Keep windows open and allow the hot air to escape (if you do not make use of air conditioners) in order to facilitate some circulation.
- Coupled with ventilation, note that the optimal temperature for alertness and participation is around 22°C. Of course, you would not want the air conditioning to cause stuffy noses as a physiological reaction, but if the room falls outside the temperature range of 18°C to 30°C, you risk losing your students' attention through thermal distraction.
- Having good rest-breaks between teaching sessions will prevent information overload and will also compensate for adjustments to the tropics and travel fatigue.
- Lastly, students need ergonomically-suitable writing and studying surfaces. This means that the tables should be at the right height with a reasonable amount of space to work on.

Teaching facilities also require the following basic planning in order to meet safety and comfort requirements:

- In the event of a fire emergency, the facility layout should permit efficient evacuation. This means that all fire hazards should be identified and managed properly and there should be adequate fire-fighting measures set in place. Remember that prevention is always better than control.
- Numerous add-ons to the electrical supply systems are common safety hazards. It is important to ensure safe installations, the protection of power outlets, and the rendering of neat wiring without creating trip hazards.
- Clean and hygienic ablution facilities should be available to students, with, if possible, separate facilities for men and women.

## The training pool

Most dive businesses that offer dive training will have their own pool or access to one nearby. A pool introduces a well-defined collection of potential risks to both divers and other users as the open water is not the only water hazard to consider. As such, we need to pay particular attention to the following:

- Protection from sunlight with sufficient shade to allow staff members and customers to complete their outdoor training activities without excessive exposure to sunlight. Put signage in place to encourage sunscreen application at least 30 minutes prior to exposure (ideally after a diver's morning shower). This is especially important in malaria areas where travellers may be taking protective medication that makes them more vulnerable to sunburn, for example doxycycline.
- The area around the pool should be surfaced so as to protect against slips and falls, especially when wet.
- Getting into the pool requires safe ingress and egress structures and procedures, especially when divers are wearing their scuba diving kits. The ladders need to be finger-pinch-proof, and the launching platforms should ensure that a practise back-roll does not result in head and neck injuries.
- Suitable access barriers around or over the pool are essential to prevent unauthorised or unsupervised access. Clients may have their young children with them and as such drown-proof barriers are crucial. In addition, supervising staff members should be trained to deal with emergencies associated with pool use.
- When training students, instructor ratios are important (as required by the respective training agency). Generally speaking, one would expect no more than six students per instructor.
- Oxygen and first-aid kits should be kept within reasonable proximity of the pool, particularly during periods of pool use, in order to ensure that medical emergencies can be rapidly and effectively dealt with.
- For pools deeper than 1.5 m, there are additional, specific accident or health concerns related to pool activities, including pulmonary barotrauma and arterial gas embolism. Such pools require a suitable accident management protocol and competent responders for dealing with such events.
- Pool hygiene is important, especially when offering services to the public. We would expect to find a logged cleaning protocol and carefully-managed hygiene controls.
- The changing rooms and ablution facilities should be available for both genders and you need to adhere to the same non-slip requirements that apply to the pool area.
- Finally, pre-dive briefings, buddy checks and post-dive briefings should be rehearsed in closed water areas to ensure safe open water excursions and to standardise safety training to all students.

Attention to these aspects, and maintaining consistent discipline in all activities related to pool dives and training, ensures that your safety record remains high. It also shows your due diligence if an unfortunate event were to occur, with your ability to mitigate both the injury and any liability.

## Transportation to the dive site

Although, in principle, passenger transportation is highly regulated in most places around the world, this is not always what we find in practice. Moreover, because this is an area where we often depend on third-party services and vehicles, the following potential risks require specific mention and attention:

- Registration and road-worthiness are vital to any form of accident and liability insurance you might have in place as well as to your public liability risk exposure.
- Drivers need to be appropriately licenced to operate the vehicle and, equally importantly, be at least 25 years of age if transporting fare-paying passengers. Remember that this is considered part of your business and is not a social event such as friends who are travelling together.



- While possibly unpopular, you do need to have an alcohol and drug policy in place, with a zero tolerance limit, if you wish to prove your commitment to safety.
- Vehicles need to be serviced regularly and also need to be checked before use every time. No drive means no dive, resulting in inconvenience and loss of revenue.
- Finally, we need to heed passenger safety requirements even though there is a general tendency to relax requirements near the beach. Wear seatbelts, do not ride on the trailer or sit on the edges and do not stand on the vehicle while it is driving.

## Transfers at the dive site

This includes the beach, the boat, the water-entry location and the dive. This is usually where the fins hit the foam! As we get to the end of the list of focus areas for our HIRA, we come to the most significant activity as far as risk management is concerned. We will focus on the boat as our primary water-entry platform, but of course the walk-in, climb-downs and the more challenging shore (rocky) entries are all part of the same water ingress-egress activities. The following guidelines will help to ensure that the risks which are associated with transfers at the dive site are mitigated:

- Does the boat meet the legal requirements? All dive boats which are used to convey passengers need to be registered and managed professionally. This implies compliance with the authorities and their specific requirements, as well as paying very specific attention to staff members' competence and the management of all boat operations.
- Boats should be registered and equipped to comply with the requirements of the local authorities.
- All working staff members need to be well-trained and certified as competent. Also ensure that the relevant certification information is filed for easy access.
- A specific alcohol and drug policy is essential, which should include documented, regular evaluations of all boat staff members.
- Boats should be equipped for possible events such as skipper overboard, engine failure, fire on board, poor weather and even for unlikely events such as capsizing or sinking.
- Night dives require additional lighting and navigation considerations.
- Lastly, effective and suitable back-up communication systems are essential for any dive operation. These should include reliable connections such as written 24-hour contact details for maritime and medical rescue services, as well as the dive business' office.

### Pre-dive

Remember that before setting out, the better prepared the excursion is, the safer it is likely to be. The actual placement of identified risks might be immediately prior to the actual dive itself, but it is better to consider them earlier rather than too late. The following is a comprehensive list of considerations to keep in mind:

- Essential boat, safety and diving spares should be available on the boat itself.
- Diving operations should ensure that they have all the necessary first-aid equipment, not forgetting preparing for hazardous marine life injuries and oxygen kits. All of these should be properly controlled, stowed and clearly marked.
- Slip and fall risks should be identified and prevented by means of engineering controls (anti-slip/friction surfaces), administrative procedures (mandating appropriate footwear) or protective equipment (providing non-slip shoes).
- One of the sad events associated with boats are propeller-related injuries. Control this risk using propeller guards, proper safety briefings, skipper attentiveness and well thought-out ingress and egress procedures.
- Instructors (in the case of students) or dive masters should be very

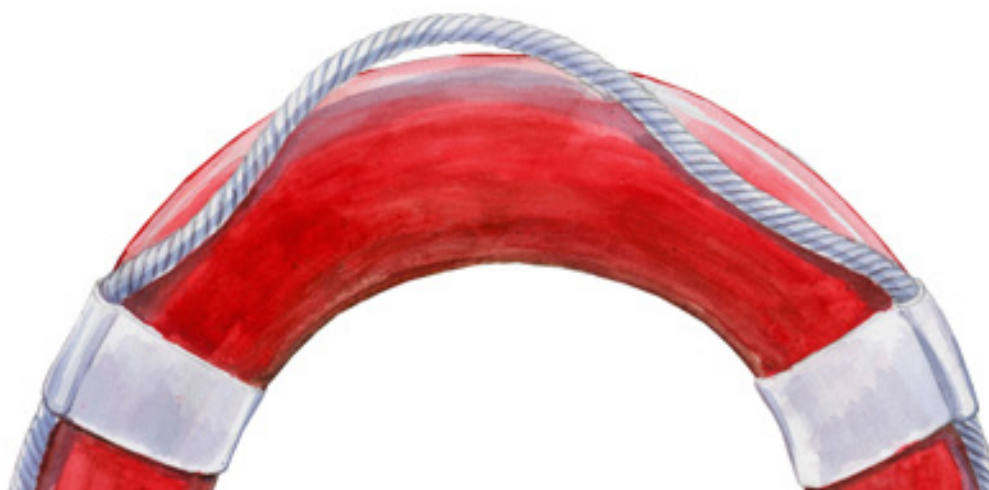
familiar with the various dive sites and should maintain appropriate ratios, for example no more than six students to one instructor and ten certified divers to one dive master.

- All divers should be suitably positioned on the boat, preferably close to their equipment as well as to their dive buddy.
- All dive equipment should be securely stowed away and divers should have their hands free to secure their position on the boat rather than holding onto equipment during the launching or return to the launch site (especially when beaching the boat).
- Rehydration should be well provided for and available to all divers.
- The best way to ensure that a thorough pre-launch check can be done is by means of a checklist. All issues such as sufficient fuel, working navigation and communications equipment, presence of first-aid kits, essential spares and tools, drinking fluids and especially the boat plugs should be diligently controlled.
- A detailed boat briefing is always required, even for the most experienced divers. All of the safety, emergency, restriction (for example no access to certain parts of the boat) and procedures need to be explained, not forgetting to instruct divers on how to get onto the boat to start with.
- Prior to the actual boat launch, the engines should be checked and suitably warmed-up to ensure that they are working correctly.
- Boat launching needs to be conducted safely. Distractions must be avoided with everyone's attention focussed on the process to avoid equipment loss or injuries. This can be assured in part by following suitable procedures, but the reality is that things still can go wrong. In these cases, it is important to carefully analyse incidents like falls, slips, bumps, losses and even more severe injuries and damages, in order to learn from them and to improve the safety procedures and the experience of the staff members.

### On the actual dive

On the actual dive it is of essence, once again, to prepare and plan beforehand to ensure a safe dive. This is a busy time, with divers moving about and often being concerned about their own state of affairs. It requires careful management and supervision, include the following:

- The diver who is in charge should always perform a thorough and well-documented pre-dive briefing. Essential elements include a dive site briefing, the sea conditions, buddy pairings and buddy procedures, communication methods, emergency procedures and the location of emergency equipment, recall procedures, any local hazardous marine life to consider, getting into the water and then out again, and of course the dive plan itself. It is also important to discuss decompression procedures and ensure that each diver has the means to monitor their depth and time.
- Kitting up instructions and the processes for individual diver checks, buddy checks and instructor or dive master checks should be clear.
- A system should be in place for logging and controlling the divers which are associated with the boat. Some sites are very busy, thus forming a diver identification helps, together with the active management of the supervising diver.
- Accident management should not only be thought about but should also be documented as a set of specific checks and procedures, be readily available at all points of contact and be workable. Rehearse the response and communication in case of an actual accident and implement the accident management procedures by means of a simulated case before any diving has actually taken place. All boat staff members need to be included in this development and rehearsal process.
- Lost diver procedures and equipment for lost-at-sea situations are a fundamental safety consideration, especially when venturing far from the shore.
- The operation needs a system in place to recall divers to the boat in the event of any emergency, deteriorating weather conditions or any other relevant emergency.



- Getting into the water needs coordination to avoid injuries, entanglements and falls, especially since most divers will already be kitted-up with equipment. The actual process of entering the water should also be addressed properly during the pre-dive briefing, but staff members will need to actively manage and monitor this process.
- The boat skipper needs to know exactly where the dive buoy and the divers are located. Also, when following a dive that is in progress, the current speed and direction should be anticipated to ensure that the boat is clear of any surfacing divers.
- The skipper also needs to ensure, when approaching divers on the completion of a dive, that they are ready to be picked up, that they are aware of the boat's position and where to climb on. It is also advisable to approach the divers in the direction of the wind, for example from the stern side.
- Be sure to involve the boat staff members in retrieving diving gear after a dive. The idea is to not have divers straining themselves during the critical period where circulating bubbles can potentially do them harm.
- Lastly, avoiding injuries during egress from the boat, for example ladder hinges crushing a diver's fingers during their exit from the water. This is the element that first inspired the HIRA Programme. Divers should ensure that the boat ladders and other supporting elements are unlikely to injure people as they get out of the water and onto the boat. Again, you may employ an appropriate combination of engineering controls, namely a good ladder design, administrative controls such as an effective procedure with appropriate instruction, and personal protection controls such as providing gear that will ensure that divers are not injured.

## Post-dive

Post-dive, there are a few practical aspects to help conclude the dive experience safely:

- A post-dive briefing should include any remaining instructions for the period between dives, such as:
  - The hazards implications of repetitive dives;
  - Considerations for the journey back to the launch site;
  - Rehydration prompts and instructions;
  - Ensuring that divers know about the no-fly period or driving over high mountains;
  - No hot showers or exercise for a total of four hours post diving;
  - An explanation of common decompression illness symptoms and the importance of reporting them regardless of the dive profile; and
  - Relevant emergency contact numbers.
- Appropriate warning and advice on post-dive swimming or snorkelling, especially if there are large marine animals to be seen. Due caution needs to be taken regarding breath-holding and deep excursions.
- Conclude all diving with the understanding of a six-hour bends watch during where no-decompression limits have been exceeded.

## In conclusion

The HIRA Programme provides some tangible and relevant safety considerations for dive businesses to include when optimising their diving operations. Note that the diligent monitoring of all incidents, accidents and even near-misses will offer the opportunity for reassessment and refinements as they offer essential feedback on whether your practices and processes are effective. These processes are not only about acquiring good safety statistics, but they are also about analysing where things do not go to plan and to develop and implement changes and to monitor the outcome to see if the problems are addressed adequately.

To quote an experienced and committed dive business owner: "We have found that once you start to put these steps in place, after a while they just become the norm and when we have new staff members to train, the existing staff members who have to do the training treat the procedures as if they had been doing them all their lives." Can there be a clearer endorsement for the HIRA process than this statement? Indeed, this should be the objective: Creating a culture of safety where safety is a perpetual habit, not a daily decision. When we set up our safety systems in a way that make sense, is effective and can be absorbed by our staff members, they become a culture rather than just another series of tasks. Then, and only then, can we reasonably expect to have a safe diving operation. This should become the signature of all successful dive operations and the minimum level of dedication all clients will come to expect.

The key to any sustainable dive business is one that is safe for its clients, ecologically responsible, in step with the needs and the means of the clients, reliable, and one that provides a safe and supportive working environment for its staff. With all of these elements intact and with a good sense of business and planning, success should be inevitable.

## Enquiries

**Tel:** 0860 242 242 (SA) / +27 11 266 4900 (int)

**Fax:** 0861 FAX DAN (329 326)

**Email:** info@dansa.org

**Twitter:** @divesafety

**Facebook:** DAN Southern Africa

**Web:** www.dansa.org



“ All divers should be suitably positioned on the boat, preferably close to their equipment.



# Additional Information

## Scuba Air Quality: What Do The Limits Really Mean?

Our knowledge-base on air quality for scuba diving has traditionally been driven by commercial and military diving practices. These empirically derived requirements were typically based on experience; either on what can realistically be achieved, or on accidents or the lack thereof.

Over the past 50 years or so, medical investigative work has been performed to determine the human impact of common contaminants in breathing air. In addition to this, occupational health and safety approaches, commonly referred to as Hazard Identification and Risk Assessment (HIRA), have been applied where other notable toxic or debilitating elements have found their way into breathing systems.

We will offer some rationale behind the contaminant limit before discussing how breathing air is analysed.

## What are these contaminants?

Contaminants can be divided into three levels that represent the likelihood of them occurring in a compressed-air cylinder intended for the diver, namely:

- Those most commonly found in compressed air (carbon dioxide [CO<sub>2</sub>], carbon monoxide [CO], moisture [H<sub>2</sub>O], condensed oil, particles and odour)
- Those found in certain geographic locations (volatile hydrocarbons and organic compounds such as methane [CH<sub>4</sub>])
- Relatively rare but reported toxic substances (for example vapours from cleaning products and halogenated solvents, emissions from motor vehicles, sulphur, and nitrogen-based products and fumes)

The air compression process can only introduce oil (vaporised or condensed), particulates and some amounts of CO<sub>2</sub> and CO. All the other contaminants, including larger amounts of CO<sub>2</sub>, CO and especially moisture, must be available in the environment in order to be present in the filled cylinder.

As a general rule, occupational health practices require that we analyse environmental conditions in the vicinity of where we are aware of potential hazards. Compressors used to produce breathing air require a thorough risk analysis prior to site selection of the compressors' intake, with consideration of weather conditions, potential local toxic fumes and exhaust from buildings or internal combustion engines.

Lubricating oils for breathing air compressors are selected on the basis of their high temperature stability, inertness and acceptability for human exposure. Finally, it remains an accepted fact that we do not monitor or analyse the air that we breathe unless we have reason to be concerned.

We therefore need to be pragmatic in our assessment of limits and, as a general rule, we know that exposure to contaminants in compressed air has mainly occurred due to a loss of controls, external influences and incidents, and where equipment has been neglected.

# Safety assessment

The following table indicates the primary safety concerns (namely human, fire and equipment safety) that apply to the contaminants we are concerned with.

## Group 1: Contaminants always potentially present in compressed air

*Compound:* **Carbon dioxide (CO<sub>2</sub>)**

*Sources:* Ambient environment, internal combustion and cooking processes, human and animal respiration, microbial breakdown of organic matter, conversion of CO to CO<sub>2</sub> in compressor filters, and motor vehicle exhaust systems.

*Human safety:* Elevated levels stimulate the respiratory centre, increasing rate of breathing. Increase in depth increases respiratory risk. Patients with high PaO<sub>2</sub> are at greater risk of oxygen-induced seizures with elevated PaCO<sub>2</sub>. Elevated levels lead to minor perceptive changes, discomfort, dizziness or stupor and finally to unconsciousness and even death.

*Fire safety:* No concerns.

*Equipment:* No concerns.

*Compound:* **Carbon monoxide (CO)**

*Sources:* Ambient environment, internal combustion processes, furnaces, gas burners, cigarette smoke and overheated compressor oils.

*Human safety:* It decreases the carrying capacity of haemoglobin, resulting in a decreased amount of oxygen available to the tissues which leads to hypoxia. A highly toxic contaminant with environmental levels magnified by increased chamber pressure.

*Fire safety:* No concerns.

*Equipment:* No concerns.

*Compound:* **Moisture (H<sub>2</sub>O)**

*Sources:* Ambient environment (humidity), drying processes (laundry), some combustion and other processes.

*Human safety:* Elevated levels of moisture are desirable (for comfort and reduced dehydration), whereas dry air inhibits growth of bacteria.

*Fire safety:* Very dry conditions enhance production of static electricity.

*Equipment:* Excessive moisture may cause regulators to freeze as adiabatic cooling takes place during pressure reduction. Regulators may fail to open causing downstream over-pressurisation of piping and equipment. Excessive moisture enhances corrosion and oxidation (rust) of air storage vessels. Excessive moisture causes filtration elements and chemicals to saturate, resulting in reduced filtration efficiency and effectiveness as well as elevated pressure drops. Excessive moisture can interact with some ultra-fine carbon filtration units generating strong chemical odours and resulting in nausea and respiratory irritation.

*Compound:* **Oil (condensed)**

*Sources:* Mostly compressor lubricating oil (introduced internally). Also from ambient evaporated oil from compressor oil leaks and surrounding equipment, motor vehicle exhaust fumes, pollens (introduced through the compressor intake), and even contaminated air pipes between the air processing plant and the chamber.

*Human safety:* Larger condensed particles are removed by the body's clearance mechanisms; smaller particles are retained and may be hazardous depending on the type and the amount (symptoms include inflammation or even rupturing of alveoli).

*Fire safety:* There are significant fire concerns, irrespective of the type of condensed oil.

*Equipment:* There is no concern at the levels usually controlled for. The maximum level of 5 mg/m<sup>3</sup> equates to a dew point temperature of -64°C, or 6 ppmv, which is significantly lower than the lowest required levels for H<sub>2</sub>O.



*Compound:* **Particles**

*Sources:* Ambient environment (micro-particles of dust and pollens); breakdown products in compressors, piping systems and filtration media; as well as post construction debris in pipes and controls.

*Human safety:* Particles smaller than 10 µm have the potential to cause shortness of breath, especially in patients with respiratory conditions, like asthma and bronchitis, as well as a reduction in the ability to resist infection.

*Fire safety:* Large concentrations of particulates can serve as a source of ignitable fuel.

*Equipment:* Larger particles are known causes of failure in pressure regulators, which may cause valves not to seal when closed and may erode valve seats, discs and seals.

*Compound:* **Odour**

*Sources:* Ambient environment and cleaning compounds used on air supply systems.

*Human safety:* It is generally only related to comfort levels. Odours from volatile, toxic or otherwise harmful substances indicate potential safety issues related to these contaminants.

*Fire safety:* There is no concern from odour. Contaminants with fire risks, including oils and volatile organic compounds, are discussed under the relevant contaminant sections.

*Equipment:* No concerns.

## **Group 2: Contaminants present in specific areas**

This group may be significantly larger than discussed here, but the following analysis serves to indicate where potential hazards may exist for clinical hyperbaric facilities. Volatile hydrocarbons include organic compounds. However, methane is the most commonly occurring compound of these compounds and is separated from the analysis. Some standards require that all hydrocarbons be grouped as a total hydrocarbon (THC) limit. This does not allow for easy identification of potential sources.

*Contaminant:* **Volatile hydrocarbons and volatile organic compounds**

They include, but are not limited to, toluene, xylene, benzene, ethane, styrene and acetone.

*Sources:* Ambient environment as a result of exposure to building materials, plastic materials, industrial chemicals, cleaning compounds, adhesives, furniture, flooring, heating and combustion processes. Overheating compressors are reported as a potential source.

*Human safety:* Generally hazardous in terms of carcinogens, neurological and narcotic effects, organ damage as well as general distress. Initial symptoms include fatigue, headaches, confusion, numbness, cardiac irritation and depression.

*Fire safety:* There are significant fire concerns in terms of low ignition temperature and low flashpoint fuels.

*Equipment:* There is no significant concern at the expected levels.

*Compound:* **Methane (CH<sub>4</sub>)**

*Sources:* Ambient environment, especially in certain geological areas and near decaying or fermenting organic matter, landfills or domestic animals (cattle). CH<sub>4</sub> may permeate buildings and enter the compressor intake.

*Human safety:* It is not toxic (may be an asphyxiant where oxygen is reduced to below 16%).

*Fire safety:* There are significant fire concerns with CH<sub>4</sub> because it is a highly flammable fuel.

*Equipment:* No concerns.

### Group 3: Rare but reported contaminants

This group is too diverse and extensive to discuss in a similar fashion to the previous two groups.

Typical contaminants include vapours from cleaning products or solvents that are not covered under Group 2 as well as environmental compounds including hydrogen sulphide ( $\text{H}_2\text{S}$ ),  $\text{SO}_2$ ,  $\text{NO}$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}_2$ ,  $\text{NO}_x$  fumes, ozone, lead compounds, asbestos and many others.

Each of these has specific deleterious effects on humans, but there are neither significant fire issues nor equipment issues – at least not in the concentrations expected in the air.

Nitrogen oxide products, loosely referred to as  $\text{NO}_x$ , are associated with decreased lung function, increased severity of respiratory problems, chronic inflammation and irreversible structural changes, amongst other related respiratory conditions and complications.

Most occupational health and safety regulations for any public enterprise provide regulations, limits and guidelines for identification and exclusion. In terms of this article, we will exclude several of these from the requirements for acceptable air quality for scuba diving and accept that they will be controlled by occupation HIRA practices.

### What are safe limits?

The limits depicted in the table below are based on the effect on the human physiology, the fire risks and the risks to equipment.

All human exposure limits are expressed as the surface equivalent value (SEV) and for the purposes of air diving a maximum depth of 50 m of seawater (MSW) is assumed. Limits tabulated are generally stated as the “noeffect level” which is the dose with no known toxic or debilitating effects.

### Finally, a note on South African regulations

Traditionally, our local regulations were contained in a standard known as SABS 019, the code of practice for transportable compressed gas containers. This regulation contained a table listing limits for impurities in compressed air for breathing. However, the latest revision of this standard no longer contains this table and instead we are referred to SABS 532 (issued in 2009 as SANS 532) which is the standard for industrial, medical, propellant, food and beverage gases, refrigerants and breathing gases.

We have lost some of the required guidance in this process and DAN-SA, together with the Compressed Gas Association of South Africa, has requested the SABS to provide an update to SABS 532 to include limits for the common contaminants of concern to scuba divers. We have hopefully provided practical, achievable and realistic limits for their consideration.



## CONTAMINANT SAFE LIMITS

	Human Exposure	Fire Risk	Equipment Risk	Achievable	SABS Limits
CO <sub>2</sub>	5 000 ppmv for pO <sub>2</sub> ≥ 3 ATA 15 000 ppmv for pO <sub>2</sub> ≤ 1.6 ATA	None	None	≤ 350 ppm <sub>v</sub> Normal air contains 300 ppm <sub>v</sub>	SABS 532: < 500 ppm <sub>v</sub> SABS 019: < 500 ppm <sub>v</sub>
CO	60 ppm <sub>v</sub>	None	None	≤ 5 ppm <sub>v</sub>	SABS 532: NS SABS 019: < 10 ppm <sub>v</sub>
H <sub>2</sub> O	RH: ≤ 50% – 60% Based on control of bacterial growth	RH: > 30% Dew point > 3°C	HP: Lowest ambient less than 44°C	Dew point -64°C based on 5 mg/m <sup>3</sup>	SABS 532: < 100 ppm <sub>v</sub> SABS 019: < 25 mg/m <sup>3</sup> < 200 bar: < 50 mg/m <sup>3</sup> > 200 bar: < 35 mg/m <sup>3</sup>
Oil	≤ 5 mg/m <sup>3</sup>	≤ 0.1 mg/m <sup>3</sup>	None at ≤ 5 mg/ m <sup>3</sup>	≤ 0.5 mg/m <sup>3</sup>	SABS 532: NS SABS 019: < 0.5 mg/m <sup>3</sup>
Particles	≤ 50 mg/m <sup>3</sup> No particles ≤ 10 µm	≤ 5 mg/m <sup>3</sup>	No limits determined	0.01 mg Size 0.5 µm	SABS 532: NS SABS 019: < 0.5 mg/m <sup>3</sup> for particles > 5 µm
Odour	None	None	None	None	None
VOC	≤ 5 ppm <sub>v</sub>	LEL ≤ 1% Limit 1 000 ppm <sub>v</sub>	None	≤ 5 ppm <sub>v</sub>	OHS requirement
CH <sub>4</sub>	≤ 5% (5 x 10 <sup>4</sup> ppm <sub>v</sub> )	LEL ≤ 5% Limit 5 000 ppm <sub>v</sub>	None	10 ppm <sub>v</sub>	OHS requirement
H <sub>2</sub> S	≤ 50 ppm <sub>v</sub>	None	>> Human limit *	≤ 1 ppm <sub>v</sub>	OHS requirement
SO <sub>2</sub>	≤ 5 ppm <sub>v</sub>	None	None	≤ 1 ppm <sub>v</sub>	OHS requirement
NO <sub>x</sub>	≤ 10 ppm <sub>v</sub>	None	None	≤ 0.5 ppm <sub>v</sub>	OHS requirement

\* Limiting factor is human and not equipment.

## Scuba Air Quality: How Do We Analyse The Air We Are Breathing?

We have discussed the contaminants we are concerned about, how to determine appropriate limits for these contaminants and we noted that the South African regulations have become a little less clear on this subject, pending a revision of SANS 532. We know that sophisticated laboratories are able to test air for practically any constituent let alone the wide array of potential contaminants. However, to be practical, the measurements need to be performed real-time, on-site and should be limited to those contaminants that are both likely to be entrained and harmful if present. Otherwise, by the time a laboratory report comes back, many cylinders might already be filled with some undesirable or unsafe pollutant.

Now we will look at how we actually determine the level of contaminants in our compressed breathing air. We will review the available techniques for the various constituents and common contaminants and then we will discuss field testing options that are available to dive operators, filling stations or even individual divers filling their own cylinders or wishing to test their breathing gas before use. Finally, we conclude with what we can do when test results approach or exceed the set limits of safety and quality.

# What are the usual analysis techniques?

The available analytical methods range from very basic, inexpensive, field testing devices to very sophisticated laboratory equipment. Most of the time, the former is enough to ensure that the compressors and filter packages are working within specification without excessive pollutants being entrained from the surrounding environment. Lower testing costs also encourage more frequent testing, which is more important in an operational setting. Usually, highly-accurate laboratory methods are reserved for forensic or accident investigations. As scuba divers, however, we do need to have some idea of how to assess the “usual suspects” of CO<sub>2</sub>, CO, water vapour and oil. The table below summarises the various field-testing options versus accuracy tradeoffs. Basically, with the exception of the detection of oil, the other stated contaminants can be field tested either using once-off detector tubes or using an electronic analyser.

In addition to the common contaminants, there is a range of other potential toxic and debilitating compounds that may enter scuba cylinders during filling. Awareness of “environmental” hazards is therefore essential and may include cleaning, industrial or even more natural compounds (such as methane produced by cows).

# What are our guiding limits?

Physiological safe limits for gas contaminants are determined by their partial pressure according to Dalton's Law. Therefore, the concentration (i.e. fgas) must be considered in relation to the maximum diving depth (the ambient pressure or Pamb). Air diving is restricted to 50 m and therefore surface equivalent values (the maximum concentration as measured at one ATA that would not be toxic at six ATA).

The limits represented in the Contaminant Safe Limits table indicate the effect on human physiology (health). In the case of oil, methane (CH<sub>4</sub>) or moisture (H<sub>2</sub>O), the limiting factors are determined by fire risks and risks to equipment.

TYPICAL FIELD ANALYSERS

Detection methods	Manual Electronic	CO <sub>2</sub> Detector tube Infrared sensor	CO Detector tube Electro-chemical sensor	H <sub>2</sub> O Detector tube Dew-point metre	Oil “Detector” N/A*
Typical accuracy	Tube Electronic	± 50 ppm <sub>v</sub> ± 25 ppm <sub>v</sub>	± 1 ppm <sub>v</sub> < 1 ppm <sub>v</sub>	± 5 mg/m <sup>3</sup> < 1 mg/m <sup>3</sup>	N/A** N/A**
Typical range	Tube Electronic	0 – 3 000 ppm <sub>v</sub> 0 – 5 000 ppm <sub>v</sub>	0 – 150 ppm <sub>v</sub> 0 – 100 ppm <sub>v</sub>	0 – 450 mg/m <sup>3</sup> 0 – 2 500 mg/m <sup>3</sup>	0.1 – 1.0 mg/m <sup>3</sup> N/A*

\*Oil vapour content (mist) is usually only measured in a laboratory (using either gravimetric or spectroscopic techniques) and is not suited to field-use.

\*\*Oil content measurement by detector tube or equivalent either provides a simple pass or fail outcome, or a specific, discrete value such as 0.1, 0.5 or 1.0 mg/m<sup>3</sup> only.



# What are the field testing options available to us?

Irrespective of whether you are testing the gas in a scuba cylinder or the gas delivered by a filling station, there are three fundamental ways to determine air quality:

- Single-use detector tubes;
- Electronic sensors; and
- Laboratory analysis.

None of these are cheap, but health and safety are at stake. This means that in the end, an appropriate compromise must be made between convenience, cost and accuracy.

## CONTAMINANT SAFE LIMITS

	Safety		Local Regulations		Best Achievable Practice
	Limit	Consideration	SABS 019	SANS 532	
CO <sub>2</sub>	≤ 833 ppm <sub>v</sub>	Safe SEV of ≤ 0.5%	≤ 500 ppm <sub>v</sub>	≤ 500 ppm <sub>v</sub>	≤ 500 ppm <sub>v</sub>
CO	≤ 10 ppm <sub>v</sub>	Safe SEV of ≤ 60 ppm <sub>v</sub>	≤ 10 ppm <sub>v</sub>	Not stated	≤ 5 ppm <sub>v</sub>
H <sub>2</sub> O	≤ 50 mg/m <sup>3</sup> ≤ 35 mg/m <sup>3</sup>	Equipment: ≤ 200 bar Equipment: > 200 bar	≤ 50 mg/m <sup>3</sup> ≤ 35 mg/m <sup>3</sup>	≤ 100 ppm <sub>v</sub> or ≤ 80 mg/m <sup>3</sup>	≤ 50 mg/m <sup>3</sup> ≤ 35 mg/m <sup>3</sup>
Oil	≤ 5 mg/m <sup>3</sup> ≤ 0.1 mg/m <sup>3</sup>	Health Fire: mixing with oxygen	≤ 5 mg/m <sup>3</sup> Not stated	Not stated Not stated	< 0.5 mg/m <sup>3</sup> < 0.1 mg/m <sup>3</sup> <sup>3</sup>
Particles	≤ 5 mg/m <sup>3</sup>	Fire	< 0.5 mg/m <sup>3</sup> particles > 5 µm	Not stated	< 0.5 mg/m <sup>3</sup> particles > 5 µm
Odour	None	N/A	None	None	None

### Where deemed to be an environmental issue

VOC	≤ 5 ppm <sub>v</sub>	Health	Not stated	Not stated	≤ 5 ppm <sub>v</sub>
CH <sub>4</sub>	≤ 5 000 ppm <sub>v</sub>	Fire	Not stated	Not stated	≤ 10 ppm <sub>v</sub>
H <sub>2</sub> S	≤ 50 ppm <sub>v</sub>	Health	Not stated	Not stated	≤ 1 ppm <sub>v</sub>
SO <sub>2</sub>	≤ 5 ppm <sub>v</sub>	Health	Not stated	Not stated	≤ 1 ppm <sub>v</sub>
NO <sub>x</sub>	≤ 10 ppm <sub>v</sub>	Health	Not stated	Not stated	≤ 0.5 ppm <sub>v</sub>

## Detector tubes and other non-reusable indicating devices

This is the age-old, tried and tested method. It is relatively simple, but not entirely fool-proof and there is always some degree of uncertainty. In recent years it has become a bit more user-friendly and the accuracy is quite acceptable as shown in the table: Typical Field Analysers. In simple terms, detector tubes are chemical reagents that are exposed to a given sample (i.e. quantity or volume) of the gas to be tested. Depending on how much of the reagent becomes discoloured as the volume of gas is passed through it, an assessment of the concentration of contaminant can be made. Detector tubes offer a visual indication of the level of contamination; easily read by even the untrained eye.

The tools needed to conduct this in the field may be as simple as some silicon tubing, a few basic flow-meters, a stop-watch and the detector tube; more sophisticated and less “hands-on” devices are available too – at a price. The new CO-Pro device, soon to be made available through DAN and some dive shops, will be an inexpensive and user-friendly “safety indicator” that can be packed into the travelling diver’s luggage without any space or safety concerns.

## Electronic analysers

With the increased use amongst recreational divers of nitrox and other blended gases, we have seen a host of hand-held oxygen and even helium analysers enter the market. Prices in real-terms have come down pretty dramatically over the past 10 years, as popularity and application have increased. Driven primarily by safety concerns, contaminant analysers have entered our market in the same way, with prices dropping steadily: Simple-to-operate, hand-held versions of CO and CO<sub>2</sub> analysers are now coming within the reach of individual divers. There are even products entering the fray that combine these with oxygen, moisture and helium, but these are still too expensive for the average travelling diver.

What we would really like to see is that our scuba filling stations invest in some of these instruments, so that regular spot checks can be made on CO, CO<sub>2</sub> and moisture levels during everyday fills. Oil vapour assessments are still a bit finicky for real-time use although at least one US-based air quality analysis company has a product that can be used on-site. Located at the local scuba-filling facility, this device communicates with the company’s laboratory over the internet and produces a result in real time that includes oil vapour determination.

## Sending a sample to an accredited air-testing laboratory

Lastly, we have a variant of the analytical method used for a highly-accurate determination of gas constituents and contaminants: ready access to a special testing laboratory for breathing gases. While not easily accessible in Southern Africa – given the high courier or postage fees – this style of assessment is popular in Europe and the US. Many dive centres make use of this service by sending in specially-prepared and easy-to-conduct test samples for their quarterly or semi-annual air quality tests. A simple process then captures the “quality” of the air on a specific date and this is then sent in to a sophisticated testing laboratory. Results are sent back via email or mail. Very effective, although the results usually only appear around seven to 10 days after the sample was taken. This option is excellent for routine assessments or for a diving accident investigation, but it does not address the concerns of a dive customer who is not happy with the “smell” or “taste” of the air in their cylinder.

For facilities using this method, we would recommend that they ask for the actual contaminant values rather than just a pass or fail certificate. This would enable the facility to monitor trends or changes in breathing air quality, which in turn might prompt timely filter changes or compressor maintenance before air quality becomes unacceptable.

For the greatest level of confidence, filling stations should be well-managed with regular air quality tests of which the results are readily visible to prospective customers who are about to buy their life-support gas from them. However, dive operations are rarely ideal settings and as we travel the diving regions of the world, this becomes readily apparent in more isolated and less developed parts of the globe. CO, moisture, CO<sub>2</sub> and oil often exceed the safety limits, and environmental hazards like methane (CH<sub>4</sub>) and nitrogen oxides (NO<sub>x</sub>) become a real concern. Costs are of course an important aspect in deciding which of the three methods to employ.

The individual, safety-conscious diver who has been alerted to reported incidents in certain dive spots might well choose to invest in a CO-Pro, disposable detecting



device or even a hand-held electronic CO monitor, ready for the day when they are concerned about their cylinder contents. This is not a significant investment all things considered and certainly better than the complications.

The quality conscious scuba-filling facility has a wider choice and a simple assessment of ongoing sampling costs (on-site or by laboratory) versus an on-site electronic, real-time analyser would be the way to make the sensible decision.

## What do we do if the levels approach or exceed the safe limits?

The second table (Contaminant Safe Limits) provides an overview of the safe, regulated and ultimately, desired limits. Where regular testing shows that air quality is approaching these limits, there are two options:

- If it is CO, CO<sub>2</sub> or some environmental pollutant that is on the rise, the compressor intake may need to be moved or secured away from the source of pollution.
- If it is primarily oil, moisture or an associated odour, the compressor and its filtration package should be assessed to decide whether the current maintenance or change-out intervals are adequate. (Note: CO can also be the product of an over-heated compressor.)

Air filtration is a topic for another day, but we do know that as a general rule moisture, oil and CO can and should be removed by the filtration package, whereas CO<sub>2</sub> will pass through without any real reduction in level. If the filtration system is not coping, it may be time to consider investing in one of our industry's recent and long overdue developments: a high-pressure refrigerant dryer. The upfront cost is quickly amortised through a significant reduction in filter replacements. Better still, there will be greater assurance of the highest quality air when it comes to oil and moisture control.

## A final note

A recent assessment of the quality of scuba air in South Africa concluded that, as a general rule, our local scuba filling stations are doing a pretty good job. This provides some assurance closer to home, but all bets are off when travelling to remote locations. Still, by simply being more aware of the relevant issues, together with an eye on product developments, divers can make better choices on what to expect, what to ensure and what to measure before sinking below the surface on oxygen-enriched exhaust fumes. Jokes aside, sub-standard air can be harmful and even fatal as was reported extensively in the media during 2012.

Science and technology have brought both knowledge and tools within our reach; we should avail ourselves of both and give ourselves a little more assurance and security.