
Market surveillance of diving air services for recreational diving

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services for recreational diving**

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Summary

On average, four deaths per year occur among recreational divers in Sweden. This can be compared with professional diving activities, which have had no fatalities. The quality of statistics on serious incidents is poor. The Swedish Consumer Agency's responsibilities include surveillance of compliance with the Product Safety Act (2004:451) and the Act on Personal Protective Equipment for Private Use (1992:1326). This means that the Agency is the responsible surveillance authority for safety in recreational diving in Sweden.

Against this background, the Agency has started a three-year project to investigate the safety of recreational diving. Work started in 2007 with a meeting of concerned parties within the sector, continuing in the autumn with surveillance visits by the Agency to 20 diving services companies, during which samples of compressed air for breathing apparatus were taken for analysis. During these visits, the Agency also inspected the company's routines for care of their compressors, filling of air and marking of air cylinders, and also checked whether the companies carry out their own air quality control.

The results of the air analysis show that diving air from five of the 20 companies (25 %) did not fulfil the requirements applicable to this air.

Of the 20 companies, 13 kept their own records of operating times and filter replacements of the compressor. Only two of the companies were able to produce records of their own air quality analyses that were not more than one year old. A further nine companies stated that, during the last year, they had checked their air quality, but the documentation was either missing or provided only inadequate information.

The investigation shows that essentially all the companies that properly looked after their equipment, and that had performed an analysis of air quality during the last year, or that regularly checked the air quality, also met the market surveillance requirements for compressed air for diving breathing apparatus. As a result of this, the Agency has published a recommendation to diving services companies that they should keep operational records and, at least once a year, perform an air quality analysis.

Participants from the Swedish Consumer Agency were Maria Lindstedt (project manager), together with Helena Nilsson and Maria Holmberg (project members).

Introduction

Some of the deaths that occur in Sweden in recreational diving occur during diver training. Unfortunately, there are no clear statistics from incident reporting. The Swedish Sportsdiving Federation has an incident database, to which divers can voluntarily report accidents and incidents. However, even in the case of accidents with fatal outcomes, it is difficult to obtain exact statistics and to find out the reasons for accidents. Material from investigations is the property of the respective police districts, and is often protected by secrecy. In addition, diving accidents are not recorded in a category of their own, but as potential drownings.

The Swedish Consumer Agency is seriously concerned that some of the fatal accidents have occurred during diver training. Recreational diving is a sport practised by many consumers. The Swedish Sportsdiving Federation estimates that there are more than 100 000 certified divers in Sweden, and over 200 non-profit-making diving clubs. In addition, there are over 70 diving shops and centres that provide diving air. There are no figures for the numbers of active recreational divers who dive regularly.

Background

The Swedish Consumer Agency's responsibilities include surveillance of compliance with the Product Safety Act (2004:451) and the Act Concerning Personal Protective Equipment for Private Use (1992:1326). This means that the Agency is the responsible surveillance authority for safety of recreational diving in Sweden. Statistics from the Swedish Sportsdiving Federation show that there is an average of four fatal accidents in recreational diving in Sweden each year. See the diagram below.

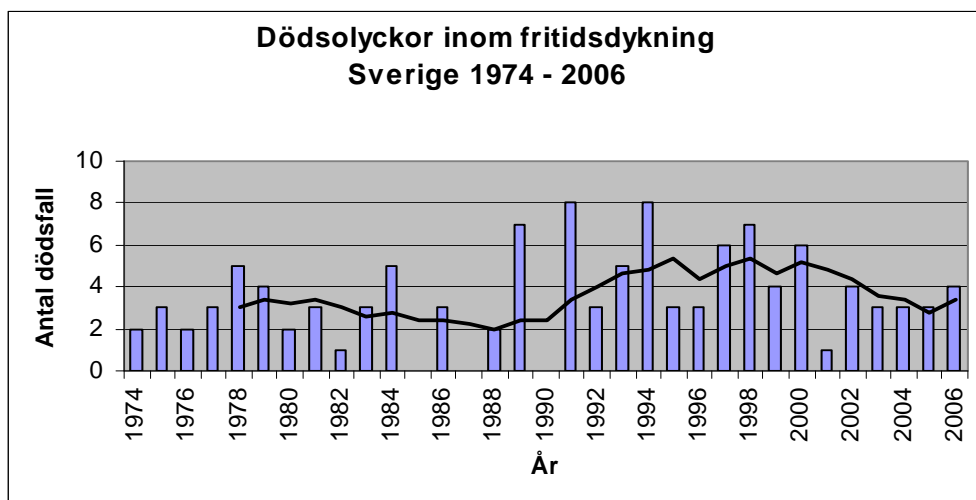


Diagram 1. Fatal accidents in recreational diving. (Source: Swedish Sportsdiving Federation.)

As far as serious incidents are concerned, there are no reliable statistics. However, information from the Swedish Diving Accident Registry at the "Östra" Hospital in Gothenburg indicates that a total of 40 divers were treated in Sweden in 2006 in recompression chambers after suffering of decompression illness. However, this is

only a fraction of the total number of incidents that occurs: there is obviously a great lack of information.

Against this background, the Agency has started a three-year project in the field of recreational diving. The work started in March 2007 with a meeting, arranged by the Agency, bringing together representatives of various public authorities and of diving interest groups in Sweden. Appendix 1 is a list of the participants.

As part of the work of the project, in the autumn of 2007 the Agency carried out market surveillance concerning the quality of compressed air for diving. Divers can use ordinary compressed air but they may also dive with other types of gas mixtures, such as nitrox, which is ordinary air enriched with oxygen. Among recreational divers, it is the use of ordinary air that is the most common. The market surveillance was therefore restricted to ordinary diving air.

The key item of equipment for providing air for divers is a compressor. There are many different types of compressors, both manual and semi- or wholly automatic. More modern compressors generally have a filter monitoring system, which monitors the machine's filters and generates an alarm when filters must be changed.



Figure 1. Compressor at one of the diving service companies

Various methods are available for checking or analysing diving air. For the purposes of this market surveillance, the Agency employed the services of Spiromec in Linköping to analyse the air using a gas chromatograph, which provides measurements with very little margin of error. The air can also be checked using other methods: diving services companies often use Dräger tubes, although they do not provide exact values but can indicate a deterioration in air quality.

When diving in cold Nordic waters, it is important that the diving air should not have too high a water vapour concentration, as this could result in blockage of

breathing equipment by ice, thus interfering with the necessary free flow of air. Nor may diving air contain substances hazardous to health. As a consumer, users are entitled to expect that the air that they buy is of good quality and safe. According to the Product Safety Act, goods and services offered by companies must be safe. Appendix 3 provides further information on the Product Safety Act.



Figure 2. Diving air cylinders

Factors that can affect the safety of diving

Many factors can affect the safety of diving. Diving air is a small part, but an important one. A report from the Department of Occupational and Environmental Medicine at the University Hospital in Gothenburg (no. 94/2002) describes the results of a questionnaire interview with a large number of dive leaders, dive masters and diving instructors. Some of the replies to the question of which factors they regarded as being capable of increasing the safety of diving were:

- Improve training, by increasing its length and setting higher standards for divers to obtain a certificate.
- Reduce the size of dive groups and increase the number of leaders for training and trips. There should be a maximum of two students per instructor.
- Better planning of all diving, and improved accident readiness. Safe diving places and always someone on shore.
- Maintenance of skills by such means as issuing certificates for a limited period of time and/or including a requirement for a certain minimum number of dives per year in order to maintain diving skills and safety.
- Better matches to the needs or standards of students/customers. Training and trips should be suited to the students and participants by prior discussion and background checks.
- Introduction of a requirement that training for diving in Sweden (cold water) must have been carried out in Sweden (or other Nordic countries).
- Improved equipment (preferably the diver's own equipment), suited to each diver.

Another factor that is important for the safety of diving is that of the attitudes and behaviour of divers. After the sector meeting with the Agency in March 2007, DYK magazine published a question on its web site with five different possible answers. The question was:

“In your experience, within which area are the greatest safety shortcomings?”

The replies indicated the following

Air/compressors 4 %
Equipment 1 %
Training 36 %
Attitudes 56 %
Other 3 %

The diving sector bears a considerable responsibility for attempting to change attitudes and behaviour. Factors that can be of importance include the carrying out of a risk analysis before every dive during training or trips, and also informing all those involved of the relevant safety rules. Another important factor is that of openness when fatal accidents and serious incidents have occurred. By learning from experience from investigations after accidents, together with good, clear incident reporting, knowledge can be improved and divers made more aware of risks.

Requirements for diving air

The limits set out in the European standard EN 12021 - 'Compressed air for breathing apparatus' have been used to determine the requirements. According to the standard, analyses must be carried out using some generally accepted method. The following limit values apply for the filling of 200 bar and 300 bar gas cylinders:

<p>Water content - Max. 25 mg/m³ Oil - Max. 0,5 mg/m³ Carbon monoxide - Max. 15 ppm Carbon dioxide - Max. 500 ppm</p>

Purpose

The purpose of the project is to reduce the number of accidents – and particularly those with a fatal outcome – in recreational diving by:

- Carrying out surveillance visits and market control of diving air, thus making the sector and consumers aware that the Swedish Consumer Agency is the surveillance authority for recreational diving.
- Collecting knowledge within recreational diving and persuading diving services companies to develop their preventive safety work.
- Establishing contacts and developing cooperation with the sector with the aim of improving procedures and starting a systematic product and services safety approach.

Questions

- Does diving air sold to consumers meet the relevant requirements?
- Have the companies adequate procedures to ensure that diving air maintains a good quality and is safe?

Method

The project started in the spring of 2007 by the Agency convening a meeting of those involved in the sector. At the meeting, the Agency and the Board of Occupational Safety and Health presented information on the split of surveillance responsibility within the diving sector. The Board is responsible for professional diving, while the Agency is responsible for safety in recreational diving. In addition, statistics of diving accidents were presented, together with a presentation and discussion of problem areas and weak points in diving. SIS Swedish Standards Institute gave a presentation of ongoing standardisation work in diving. The meeting was concluded by the Agency with a presentation of the planned market control of diving air and other planned projects during the three-year period.

In June 2007, in order to reach and inform as many diving companies and diving clubs as possible, the Agency sent out a letter with information on the project. Information on the Agency's three-year recreational diving project has also been published on its web site at www.konsumentverket.se

The autumn inspection was then carried out by visits to 20 diving service companies in Sweden, concentrating on diving shops and centres. Selection of the specific shops and centres was sample-based, concentrated on areas in Sweden having the greatest number of diving clubs. Only one diving club was included in the inspection. During the visits, samples of diving air were taken for analysis, which was carried out by Spiromec in Linköping, who also supplied the sampling cylinders for the air. The results of the analysis should be seen as those from a snapshot test, indicating the quality of the air supplied by the compressor at the time of taking the sample.

In order to ensure good, continuous air quality, companies must have good working procedures. The Agency has therefore also inspected the companies' procedures for looking after compressors, filling cylinders with air and marking of cylinders. The companies were also asked to show analysis records from their own air analyses, or some other documentation confirming that they have carried out their own quality tests. In addition, the positions of air inlets to compressors, and the placing of filling stations for diving cylinders, were checked.



Figure 3. Filling station for diving air.

Earlier investigations

The Swedish Consumer Agency carried out a market surveillance inspection of diving air in 1996. Nine air samples were taken for analysis, with one being failed due to too high an oil concentration. In connection with this work, a brochure was produced in conjunction with the diving sector, entitled “*Air for diving – a matter of life and death*” (in Swedish). The brochure can be downloaded from www.konsumentverket.se

Analysis and results

A total of 20 diving services companies was visited: only one diving club was included in the inspection, which was concentrated on companies selling equipment and providing diver training, diving expeditions and diving air. The following companies were visited:

Name of the company	Date of sampling
1. Aqua Sport, Stockholm	2007-09-13
2. Aquatica, Limhamn	2007-09-26
3. Dykhuset, Stockholm	2007-09-12
4. DykLeif, Hamburgersund	2007-09-05
5. Dykmagasinet, Karlstad	2007-10-08
6. Dykterminalen, Halmstad	2007-09-27
7. Dykterminalen, Malmö	2007-09-25
8. Fantasea, Stockholm	2007-09-12
9. Flying Divers, Göteborg	2007-09-06
10. H ₂ O Diving, Lund	2007-09-26
11. Karlstad Diving Club	2007-10-12
12. Kon-Tiki, Smögen	2007-09-04
13. Malmö Dyktjänst	2007-09-25
14. Oxygene Diving, Göteborg	2007-09-06
15. Oxygene, Lysekil	2007-09-04
16. Oxygene, Örebro	2007-10-11
17. Stockholms Dykcenter	2007-10-09
18. Waterhouse, Stockholm	2007-09-13
19. West Point Divers, Tanumstrand	2007-09-05
20. Ängelholms Dykcenter	2007-09-27

Results, diving air

Of the 20 samples, 14 were taken from compressors having automatic filter monitoring. The other six were from compressors for which the company is itself responsible for checking service times and need for replacement. The results of the analysis show that five out of the 20 companies (25 %) did not meet, at the time of taking the samples, the requirements concerning the quality of diving air. It is worth noting that three of these companies had filter-monitoring systems that should automatically generate an alarm when filter replacement is required. See Appendix 2 for complete results of the analysis.

Water content

Three of the companies had excessive water content in their diving air. The water content of the air supplied by the compressor must be less than 25 mg/m³: too high a concentration can result in ice formation in the breathing equipment as a result of cooling as the compressed air expands. The compressed air in a cylinder expands (i.e. the pressure is reduced) as part of the process of delivering it to the diver. As it expands, so does it also cool. This can result in freezing of any water vapour and malfunction of the breathing equipment, resulting in free flowing of gas. The risk of freezing increases with diving in cold Nordic waters. Too high a water content can also introduce the risk of rust formation in diving cylinders. Rust can block the flow of air and shorten the life of the cylinders.

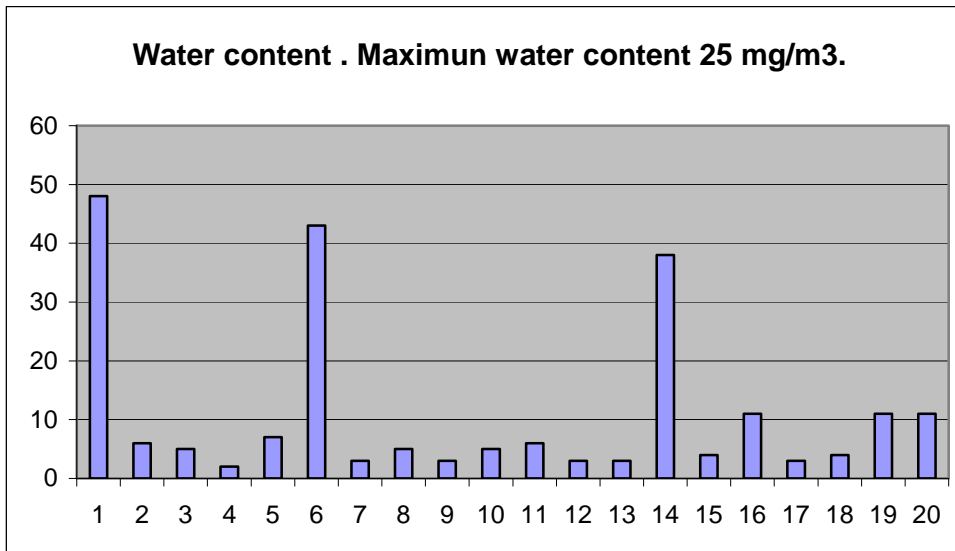


Diagram 2. Variation of water vapour concentration among the samples

Carbon dioxide and carbon monoxide

Two of the samples exhibited elevated carbon dioxide concentrations. No samples showed elevated concentrations of poisonous carbon monoxide. Carbon dioxide is a common gas in our surroundings, and elevated concentrations in diving air can indicate poor quality of intake air to the compressor. If the air intake is situated in the compressor room, it is therefore important to ensure good ventilation and air change.

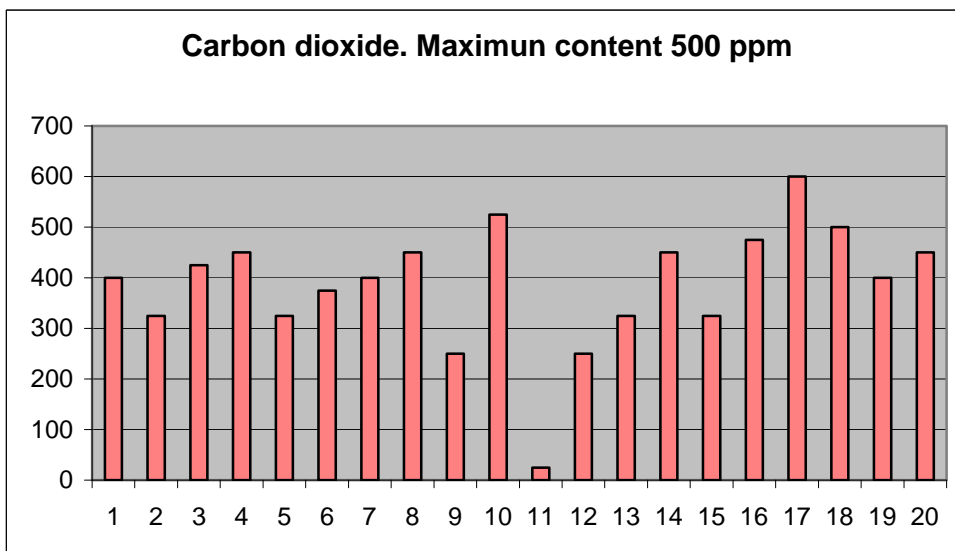


Diagram 3. Measured carbon dioxide concentrations in diving air samples

Oil

None of the samples had too high concentrations of oil. Oil can contaminate diving air by breaking down to carbon monoxide and other contaminants. This can occur if the compressor is too hot, e.g. if it is situated in a poorly ventilated area with no cooling.

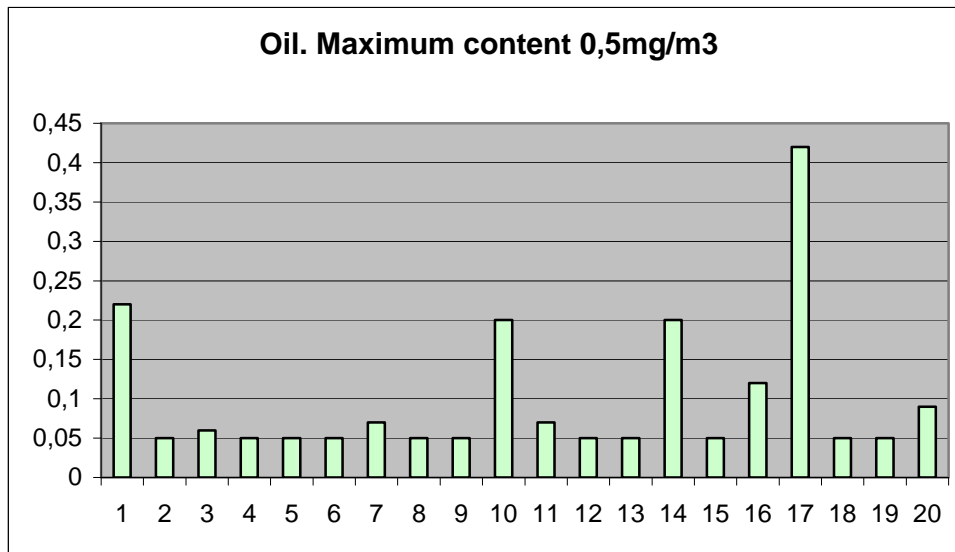


Diagram 4. Variation of oil concentration in the diving air samples

Other results

Companies' own air analyses and operating logs

Two of the companies were able to produce their own analysis records that were less than a year old. A further nine companies stated that they carried out their own tests using Dräger tubes, or had employed the services of some other company for their air tests. Documentation from the Dräger tube tests is often inadequate. Nine companies had no own analysis records, or could produce only old test results.

Not all the companies kept operating logs. 13 of them were able to produce relevant records. Asked why they did not check and note service times, filter replacements and oil inspections, most of the other companies replied that they felt that it was unnecessary, as they relied entirely on the automatic filter monitoring systems. Another response was that the company had recently changed owner, and had not properly started with all procedures.

Filling stations and marking of diving cylinders

The commonest way of marking filled cylinders is by applying a tape over the valve and placing the cylinders in a special position. Only three of the companies marked their filled diving cylinders with a label indicating that the cylinder is full, the date when it was filled and the name of the person who filled it. There are also some companies that did not mark their cylinders at all: instead, they require customer cylinders to be marked with the customer's own name or some other form of identification marking. When the customer collects the cylinder, he/she is advised to check the cylinder pressure using a special pressure gauge.

In six cases, the filling positions for diving air were unsuitably positioned at the entry to, or inside, the shop.

Compressor air intake positions

In eight of the companies, the compressor air intake was in the same room as the compressor itself. This requires good ventilation/air change. In other cases, the air was drawn from outside, from courtyards and roofs, or directly from a lightly trafficked road.

Practical experience from the market surveillance inspection

One purpose of the inspection has been to gather knowledge and understanding of how diving service companies operate. Summarising, it can be said that no one company is like another. There are some that provide only diving air and diving trips, but the most common pattern is for the companies to offer all types of products and services. This includes sales and service of diving equipment, sale of diving air, diving training and diving trips. Some of the clubs belonging to the Swedish Sportsdiving Federation (SSDF) offer training and trips at cost price, although only to members of the Association.

Some of the companies had no written procedures at all for maintaining the compressor, filling air etc., while others operate a comprehensive preventive product safety scheme. A good example can be application of:

- Written procedures for looking after the compressor and air filling
- The keeping of records concerning the compressor and results of air analyses
- Instructions and a rescue plan for each diving site
- A review of the planned dive, together with a description/sketch of the area, prior to each dive
- Dives with a limited number of pupils, in order to ensure that the pupils are always in sight and any incidents can be dealt with
- Matching of training and trips to the standards of pupils and customers.
Diving skills to be established through dialogue and questions.

In the surveillance inspection operation, the Agency asked companies how many pupils they felt that instructors should have in each group when training and diving outdoors. The replies varied from two to eight pupils. Many felt that two is the optimum number from a safety point of view. Others choose to split up larger groups, with two pupils at a time being in the water and carrying out exercises. An alternative is to have diving assistants. However, there are also companies that dive with up to eight pupils per instructor, and only one assistant.

Feedback to the companies

The results of the report and of the air analyses have been sent out to each participating company. In addition, those companies that did not meet the air analysis requirements have been given written notice of requirement to improve. Three companies have also been instructed to arrange for a new analysis after appropriate improvement steps have been taken, and to send a copy of the results to the Agency.

Conclusions

The investigation shows that essentially all the companies that properly maintained their equipment, and had arranged for an air analysis within the last year or performed regular checks using Dräger tubes, also satisfactorily passed the diving air inspection. All the companies that were visited stated that diving air was important, and that it was in their own interest that the air should fulfil the applicable safety requirements. Nevertheless, as many as 25 % of the companies did not fulfil the requirements.

This surveillance inspection of diving air should be seen as a snapshot test, showing the quality of the air at the time when the samples were taken. A prerequisite for being able to offer consumers diving air that meets the requirements is that the companies should apply good preventive routines for looking after the compressors and for filling air cylinders. Regardless of whether a company has a fully automatic compressor with a filter monitoring system or not, its personnel should keep detailed operating records. Such records must show the operating time of the compressor and times/dates of filter replacement and, in certain cases, of oil changes. (Several companies have service agreements with other companies for annual maintenance service and oil change.) Air analyses should be carried out annually, and can be complemented by simpler checks using Dräger tubes. When taking samples of the air for analysis, the companies should take them just before a planned filter replacement, in order to ensure that the air is of a good quality between replacements. This recommendation has been included in the letter sent by the Agency to all the participating companies.

Another important factor is that the intake air to the compressor should be of good quality, regardless of whether it is inducted from outside or directly from the room in which the compressor is installed. In those cases where the air intake is in the compressor room, ventilation and air exchange quality must be good.

Consumers who are divers, or who want to start diving, should demand that their diving service company can show an analysis certificate for the diving air. This certificate should not be more than one year old.

Sources

Report from the Department of Occupational and Environmental Medicine, University Hospital, Gothenburg (94/2002): "Prevention of diving-related accident traumas" [*in Swedish*] ISSN 1650-4321 ISBN 91-7876-093-3

EN 12021 – Compressed air for breathing apparatus

Swedish Consumer Agency brochure: "Air for diving - A matter of life and death" [*in Swedish*]

Appendices

Appendix 1. Participants at the sector meeting

Appendix 2. Results of diving air analyses

Appendix 3. A brief overview of the Product Safety Act

***Participants at the sector meeting, recreational diving,
19 March 2007***

<u>Company, organisation</u>	<u>Name</u>
PADI	Olle Olsson
CBM	Chris Flodén
Poseidon	Kurt and Jens Sjöblom
Interspiro	Ola Lindh
DYK (magazine)	Martin Örnroth
Maritime Safety Inspectorate	Tommy Johansson
Swedish Maritime Administration	Mats Rosander
Swedish Rescue Services Agency	Sören Lundström
Ingenjörfirma Kurt Nyberg	Christer Nyberg
Åhrmans dykeri	Rolf Åhrman
Aviation and Marine Medicine Centre	Wille Bergöö
Dykexpert	Stig Lundin
Swedish Sportsdiving Federation	Hans Örnhagen
SIS, Swedish Standards Institute	Mats Söderlund
Swedish Work Environment Authority	Bengt Husberg
	Janez Marinko
Swedish Consumer Agency	Maria Lindstedt
	Helena Nilsson
	Jan Sjögren
	Åsa Persson
<u>Unable to attend</u>	
Oxygene Scandinavia	Henrik Almers

Results of air analyses

Name	Water (max. 25 mg/m³)	Oil (max. 0,5 mg/m³)	CO (max. 15 ppm)	CO₂ (max. 500 ppm)
Aqua Sport	48	0,22	5	400
Aquatica, Limhamn	6	0,05	5	325
Dyk Leif	2	0,05	5	450
Dykhuset Stockholm	5	0,06	5	425
Dykmagasinet, Karlstad	7	0,05	5	325
Dykterminalen,Halmstad	43	0,05	5	375
Dykterminalen, Malmö	3	0,07	5	400
Fantasea Stockholm	5	0,05	5	450
Flying Divers, Göteborg	3	0,05	5	250
H2O Diving, Lund	5	0,2	5	525
Karlstads dykarklubb	6	0,07	5	25
Kon-Tiki, Smögen	3	0,05	5	250
Malmö Dyktjänst	3	0,05	5	325
Oxygene Diving, Göteborg	38	0,2	5	450
Oxygene, Lysekil	4	0,05	5	325
Oxygene, Örebro	11	0,12	5	475
Stockholms Dykcenter	3	0,42	5	600
Waterhouse	4	0,05	5	500
West Point Divers Tanumstrand	11	0,05	5	400
Ängelholms Dykcenter	11	0,09	5	450

A brief overview of the Product Safety Act

The Swedish Consumer Agency is the surveillance authority having jurisdiction in accordance with the Product Safety Act (2004:451), referred to below as PSA. The purpose of the Act is to prevent goods or services from causing injury to persons. Under the terms of the Act, only safe goods or services may be provided by commercial businesses.

A product or service is safe if, during normal and reasonably foreseeable use and duration of life, it does not present any risks to human health and safety, or only a low risk. According to the Act, a product that complies with a standard that is an implementation of a European standard is deemed to be safe in respect of risks covered by the standard. If a product departs from the requirements of a standard, this can be a strong indication that it does not fulfil the safety requirements of the PSA.

A product that does not meet the safety requirements is, in the terminology of the PSA, dangerous. If a business supplies a dangerous product, it leaves itself open to action under the terms of the PSA. If remedial measures of corrective actions are necessary, the Swedish Consumer Agency is required to negotiate with the business concerned with the aim of making the latter voluntarily apply any necessary corrective actions etc.

If voluntary actions are not taken, the Agency can forbid the business to supply a product or service, to provide safety or warning information and/or to recall a product or service. Such injunctions or orders shall be backed by penalties, unless there are special reasons to indicate that penalties would be unnecessary. A business that either deliberately or as a result of carelessness fails to do what is necessary in order to ensure that products supplied by it are safe can be required to pay a sanction fee of not less than SEK 15 000 and not more than SEK 5 million. (Sanction fees may not be levied in connection with infringement of a ban or failure to comply with an injunction supported by penalty.)

A business that has supplied a dangerous product or service shall without delay take the necessary steps to prevent cases of damage or injury. In addition, the business shall immediately notify the Swedish Consumer Agency. Manufacturers shall operate a preventive product safety programme with the aim of identifying risks of damage or injury caused by the products that they provide or have provided.

The full text of the Product Safety Act, together with information setting out the obligations of businesses under it, is available on the Agency's web site, www.konsumentverket.se. The site also provides forms for notifying dangerous goods or services: see under the tab "For companies" and then "Product safety".



Swedish Consumer Agency
Box 48
SE-651 02 Karlstad, Sweden
Telephone: +46 771 42 33 00
Webbaddress: www.konsumentverket.se
E-mail: konsumentverket@konsumentverket.se