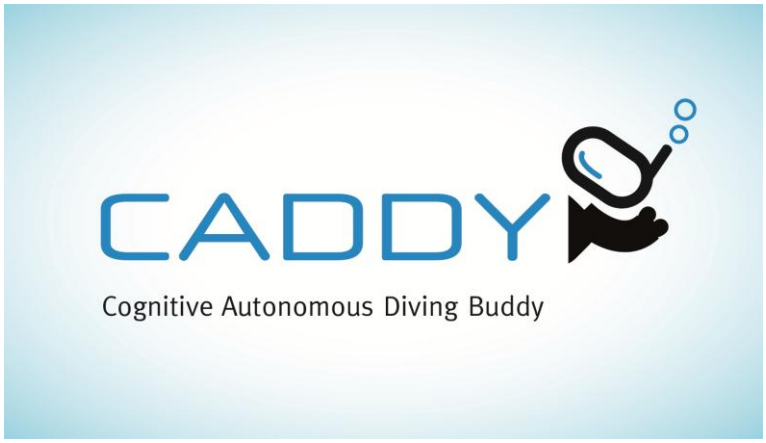
Grant Agreement No. 611373



FP7-ICT-2013-10

D6.1.1. Safety rules for the development of diver assistance system components

Due date of deliverable: 28.02.2014
Actual submission date: 28.02.2014

Start date of project: 01 January 2014 Duration: 36 months

Organization name of lead contractor for this deliverable: DAN EUROPE

Revision 1.0

Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

1 INTRODUCTION

1.1 Scope of Work

The primary aim of this deliverable is to provide initial design guidelines for ensuring diver safety by building a regulatory framework for the acceptance of robotics in the diver community. This task will be active during four periods of the CADDY project. During the first period, the existing vehicles that will be adapted for the purposes of the CADDY project is evaluated regarding safety issues. This will mainly focus on the vehicles' maneuvering capabilities as an indicator of whether the vehicles are safe to be used for interaction with divers. The hazards of ancillary equipment such as scaling LASER2s and acoustic modems or relocators are addressed as well. Whenever necessary, the vehicles should be adapted (within WP1) according to the deliverable D6.1.1.

1.2 Liability Disclaimer

The analysis and design requirements compiled in this report are prepared for the vehicle list provided by the project partners, and cannot be used as a general guideline for other submersible AUV's or Robot operations. D 6.1.1 applies only to the following devices:

Table 1 CADDY- JACOBS Vehicle: Muddy Waters II

Vehicle:	**Muddy Waters II (AUV)**	**New AUV (TBD)**
W x L x H [mm]	700 x 1500 x 600	TBD: ca. 700 x 1500 x 1500
Weight (in air) [kg]	80 (incl 14kg weights)	TBD: up to 100kg, including sensors
Depth rating [m]	~5m	TBD: ~100m
Speed [kn]	Unknown	TBD
Battery	Lipo, 48V, 10Ah	TBD: ~1kWh
Thrusters	8x seabotix BTD150, 100W	TBD
	configuration: 4x surge, 2x heave, 2x sway	
Sensors & Equiptment	2x tritech micron scanning sonar	TBD: Tritech micron echosounder
	2x wide angle cameras	TBD: DVL
	2x tele cameras	TBD: depth sensor
	4x halogen lights	TBD: Uniquiti Bullet M5 HP (5.4GHz)
	Wifi comms (5 and 2.4 GHz)	TBD: Evologics s2cr modem with usbl
	Fiber optic tether	GPS, AHRS (with magnetometer)
	GPS, XSens AHRS (with magnetometer)	Optional: stereo camera (bumblebee or other)
		Optional: reson seabat 7125 auv multibeam

Table 2 CADDY - UNIZG Vehicle: Buddy - AUV

Specification of underwater and surface vehicles used in CADDY - UNIZG			
	SeaMor 300F - ROV	**PlaDyPos - Platform for dynamic positioning**	**Buddy - AUV**
W x L x H [mm]	355 x 472 x 355-500 (depending on the payload)	707 x 707 x 400	TBD - cca. 620 x 800 x 500
Weight (in air) [kg]	20-35 (depending on the payload)	30	TBD - cca. 40
Depth rating [m]	300	-	TBD - up to 100
Speed [kn]	2	2	TBD
Battery	No, Main supply 48VDC via Tether	21A @ 18,5V - 388,5Wh	TBD - 22A @ 46,8V - cca. 1000Wh
Thrusters	Horizontal 2x150W	Horizontal in X-configuration 4x100W	TBD - Horizontal in X-configuration 4x150W
	Vertical/Lateral 2x150W		TBD - Vertical/Lateral 2x150W
Sensors & Equipments	Compass, roll and pitch	GPS, Compass, roll and pitch	GPS, Compass, roll and pitch
	Depth	USBL Tritech, used for underwater positioning	Depth
	DVL, LinkQuest 600 Mini, determine the velocity vector and altitude of a subsea vehicle moving across the sea floor	DVL, LinkQuest 600 Mini, determine the velocity vector and altitude of a subsea vehicle moving across the sea floor	DVL, LinkQuest 600 Mini, determine the velocity vector and altitude of a subsea vehicle moving across the sea floor
	LYYN video optimization in controller	GoPro Hero3 camera for 2D mosaic in shallow water	TBD - USBL
	DVR video recorder	Ubiquiti Bullet m2 HP wireless	Detachable fiber optic link with the surface
	Front looking Dual frequency sonar system BlueView DF900/2250. Provides the medium and ultra-short range imaging required to perform complex tasks in zero visibility conditions	Underwater tablet for diver with fully functional touchscreen	Back/Bottom Low Light IP HD camera (Bosch NIN-733-v03PS), Min 0.017 lx, 720p, motorized zoom/focus and custom made tilt
	Color CCD Camera(FCB1X10A Sony), 1.5 lux min, focus manual/auto, zoom 40:1 (10x optical, 4x digital), tilt 180 Degree and 2x50W var. intensity light (tilt with camera)		Front stereo camera Bumblebee® XB3, Three Sony 1/3" progressive scan CCDs, BW
	USBL Tritech, used for underwater positioning		Tablet for visual communication and fully functional touchscreen
			TBD - Front looking, Dual frequency, High resolution sonar

Table 3 CADDY- CNR Vehicle: e-URoPe ROV/AUV (AUV Mode only)

	Charlie USV	e-URoPe ROV/AUV
W x L x H [mm]	2400 x 1700 x 500	TBD - 900 x 600 x 600
Weight (in air) [kg]	300	TBD - 70
Depth rating [m]	-	TBD - up to 100
Speed [kn]	up to 1	TBD - up to 0.5
Battery	2 x Li-Ion 25,2V @ 93 A/h	TBD - Li-Ion …
Thrusters	2 horizontal thrusters combined with rudder system	4 horizontal thrusters, 4 vertical thrusters, thruster type Brushless motor 120W
Sensors & Equipments	GPS	GPS
	Magnetic Gyro Compass	USBL Tritech, used for underwater positioning
	Inclinometers	DVL
	Anenometer	USBL / Acoustic modem
	Acoustic altimeter (payload)	CTD
	Side-scan sonar (payload)	Altimeter
	Bottom looking cameras (payload)	Cameras
	Acoustic modem	Fiber Optic data link (in ROV mode)
	Wifi data link	

Table 4 CADDY- IST Vehicle: MEDUSA-D

Underwater and Surface vehicles used in CADDY - from IST Specifications regarding				
	DELFIM	**DELFIM_X**	**MEDUSA_S**	**MEDUSA_D**
				
Type	ASV	ASV	ASV	AUV
W x L x H [mm]	2000 x 3500 x 1500	2430 x 4500 x 1500	350 x 1035 x 875	350 x 1035 x 875
Weight (in air) [kg]	300	350	23	30
Depth rating [m]	-	-	-	50
Max Speed [kn]	5	5	3	3
Battery	Lead Acid + LiPo	Lead Acid + LiPo	830 Wh LiPo	830 Wh LiPo
Propulsion	Electric Thrusters, Horizontal 2x 1100W, Transom mount column type of transmission, Open bladed propellers, propeller diameter 280 mm	Electric Internal, Horizontal 2x 1000 W, "Sail drive" type of transmission, Open bladed propellers, propeller diameter 240 mm	SeaBotix Electric Thrusters, Horizontal 2x 200W ducted propeller, propeller diameter 76 mm, max object size able to reach the propeller about 15 mm	SeaBotix Electric Thrusters, Horizontal 2x 200W + Vertical 2x 200W, ducted propeller, propeller diameter 76 mm, max object size able to reach the propeller about 15 mm
Sensors & Equipment	RTK GPS	RTK GPS	Ashtech RTK GPS	Ashtech RTK GPS
	Attitude Sensor	Attitude Sensor	VectorNav Attitude Sensor	VectorNav Attitude Sensor
	Wi-Fi air comms - Ubiquiti Bullet HP	Wi-Fi air comms - Ubiquiti Bullet HP	Wi-Fi air comms - Ubiquiti Pico HP	Wi-Fi air comms - Ubiquiti Pico HP
	Radio modem - Freewave 900 MHz	Radio modem - Freewave 900 MHz	Echo-sounder - Tritech Micron 500kHz very low power	Echo-sounder - Tritech Micron 500kHz very low power
	Log (acoustic correlation type)	Log (acoustic correlation type)	Bowtech Camera	Bowtech Camera
			Evologics USBL/Acoustic Modem 18-34 kHz low power	Evologics USBL/Acoustic Modem 10-34 kHz low power
				LinkQuest 600 micro DVL, 600 kHz very low power
				Tritech Micron sonar (Forward Looking Mechanically Scanning Sonar), 650 - 750 kHz very low power
Hull type and construction materials	Catamaran, Plywood + fiber glass, sharp edges	Catamaran, Round hull, SP sandwich construction	Twin acrilic cylinders + carbon fiber round nose and tail cones	Twin acrilic cylinders + carbon fiber round nose and tail cones
Basic capabilities	Heading Control, Hold Position, Path Following, Cooperative Path Following	Heading Control, Hold Position, Path Following, Cooperative Path Following	Heading Control, Hold Position, Path Following, Cooperative Path Following	Heading Control, Hold Position, Path Following, Cooperative Path Following
Emergency Stop	Kill switch on both hulls	Kill switch on both hulls	Under development	Under development
Acronyms				
ASV	Autonomous Surface Vehicle			
AUV	Autonomous Underwater Vehicle			

ROV's and ASV are NOT included within the scope of this work due to the additional risks such as the existence of tether and the high DC voltage. The users may benefit from the industry standards for the safe use of ROV's underwater at their own risk:

Code of Practice for the Safe & Efficient Operation of ROV's - IMCA R004, Rev 3, International Marine Contractors Association (IMCA) Publications, December 2009.

Guidance document and competence tables: Remote Systems & ROV Division, - IMCA C005, Rev 3, International Marine Contractors Association (IMCA) Publications, 2011.

High voltage equipment - Safety procedures for working on ROVs. IMCA R005, Rev 1, International Marine Contractors Association (IMCA) Publications, 2003.

ADCI Diving with ROV's, Consensus Standards for Commercial Diving and Underwater Operations. Association of Diving Contractors International (ADCI) Publication, Fifth Edition, Section 4.29, 4-40, 2003.

Remotely operated vehicle intervention during diving operations, ADCI publication 032,rev1. 1992.

The safety rules listed in this communication are derived from the experience of many diving accident, irrespective of being linked to the AUV's. They should be interpreted as lessons learned and may not be always extrapolated to an AUV environment and they do not warranty the safe operation of AUV's by any means. The AUV designers must adhere to the common standards of safety for Human - Machine interaction; to list the major ones:

- ISO 10218: Safety requirements for industrial robots
- ISO 12100: Safety of machinery – General principles for design – Risk assessment and risk reduction
- ISO 13849: Safety of machinery – Safety-related parts of control systems
- ISO 13850: Safety of machinery – Emergency stop – Principles for design
- ISO 13854: Safety of machinery – Minimum gaps to avoid crushing of parts of the human body
- ISO 13855: Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body.
- ISO 13857: Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs
- ISO 14738: Safety of machinery – Anthropometric requirements for the designs of workstations at machinery
- ISO 13482: Robots and robotic devices – Safety requirements for personal care robots service ANSI/RIA R15.06-1999. American National Standard for Industrial Robots and Robot Systems — Safety Requirements American National Standards Institute, Inc. June 21, 1999
- IEC 62061 Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems
- IEC 60204 Safety of machinery
- IEC 61310 Safety of machinery – indication, marking and actuation – Part 1 Requirements for visual, acoustic and tactile signals
- IEC 62046 Application of protective equipment to detect the presence of persons
- IMCA D002 Battery packs in pressure housings
- IMCA D039 FMEA guide for diving systems
- IMCA D045 Code of practice for the safe use of electricity under water
- IMCA D046 Considerations for the safe operations of autonomous underwater vehicles (AUVs)

Failure to disregards these standards and the D6.1.1 may result in serious injury or death.

Underwater world is considered to be an extreme environment for human physiology. Proper training, adequate physical fitness and precautionary measures such as the ones listed in D6.1.1 may reduce the likelihood of underwater accidents and incidents; however will not inherently eliminate the risk of serious injury or dead. DAN Europe is not responsible for any personal injury, as well as the loss or damage of equipment arising from the nature of the underwater environment.

2 HAZARD IDENTIFICATION - POTENTIAL RISKS

There are two possible purposes in identifying hazards:
1- To obtain a list of hazards for subsequent evaluation using other risk assessment techniques. This is sometimes known as “failure case selection”.
2-To perform a qualitative evaluation of the significance of the hazards and the measures for reducing the risks from them. This is sometimes known as “hazard assessment”.

Following hazards were identified for the CADDY project:

2.1 Immersed human body - Man Underwater

All risks of SCUBA Diving due to immersion & pressurised environment must be listed.

This part must include Fitness to dive as well. To be prepared by the end of March

2.2 Man - Machine interactions

2.2.1 Trauma

Considering the payload and the speed of the AUV's listed at the introduction, they are less likely to cause any lethal trauma by direct collision except that the collision area is the face or by a direct hit of the propeller. It this case, AUV's not only cause a deadly trauma but may also hit the regulator and may cause the loss of primary gas supply.

2.2.2 Electrical shock

The hazards of the use of electricity underwater were perfectly described in IMCA document IMCA D 045, R 015, Code of Practice for The Safe Use of Electricity Under Water. All other risks associated with the use of electric power under water (mechanical risks, non-electric burns, ionising radiation, and generation of sound, ultra-sound and shock waves) are excluded. The most obvious of these is electric shock and the prevention of this is the primary intent of the Code. In addition, degradation of electrical insulating material by heat can result in the emission of toxic or explosive products, and hot surfaces or electric arcs from faulty equipment or switching devices can ignite some gas mixtures and pollute the diver’s breathing gas supplies. Information on the prevention of these hazards is included in the Code.

2.2.3 Acoustical trauma

Divers exposed to high levels of underwater sound can suffer from dizziness, hearing damage or other injuries to other sensitive organs, depending on the frequency and intensity of the sound. This may

include neurological symptoms such as blurred vision, lightheadedness, vibratory sensations in hands, arms and legs, and tremors in upper extremities (1, 2, 3).

Sound Metrics

A number of different measures, each expressed in different measurement units, can be used to characterize underwater sound. The sound metrics used in this assessment are:

Sound Pressure Level (SPL), which is the change in pressure as a sound or pressure wave passes. SPL is often expressed on a logarithmic scale in decibels (dB) relative to a standard reference pressure, calculated as:

$$SPL = 20\log_{10}(P_t/P_{ref})$$

where Pt is the sound pressure at time t and Pref is the reference pressure. In seawater the standard reference pressure is 1 µPa. Because decibels are on a logarithmic scale they are not linearly related to perceived loudness. A 3 dB increase represents a doubling of sound pressure, and a 10 dB increase represents a tenfold rise in pressure.

Peak Pressure (Pmax), the maximum instantaneous positive SPL over the duration of the sound exposure. In the present assessment peak pressure is expressed in dB re 1 µPa.

Peak to Peak Pressure (PPP), the algebraic difference between maximum instantaneous positive and negative SPL expressed in dB re 1 µPa. This metric is 6 dB higher than the Peak Pressure.

Sound Exposure Level (SEL), the time integral of sound pressures received over the duration of exposure, which reflects the total sound energy received during exposure. This measure recognizes that the effects of sound are a function of exposure duration as well as maximum instantaneous peak pressure. SEL allows comparison of short exposures to high sound pressure levels with longer exposures to lower pressure levels. SEL is referenced to both a reference pressure (1 µPa) and an exposure duration (1 s), and has units of dB re 1µPa2s.

There is wide agreement that Pmax and SEL are appropriate measures for assessment of sound impacts on marine animals (4,5). Note that McCauley *et al.* (2000) refer to SEL as “equivalent energy”.

Published data from humans under water in literature are scarce and sometimes use different terminology with regard to sound levels. For example sound pressure levels measured in air are normally reported with a reference pressure of 20uPa whereas levels measured in water are normally reported with a reference pressure of 1uPa. Therefore, in the diving environment it is recommended to use SPL (sound pressure level) threshold with reference pressure of one micropascal (1 µPa) for both water and air measurements in order to compare values from different sources (6, 7).

The second mechanism of acoustical trauma is postulated to occur by resonance of the gas containing tissues such as lungs, sinuses etc. A recent workshop on acoustical trauma that whereas the preceding

logic makes it seem unlikely that acoustic resonance in air spaces played a primary role in tissue trauma, nevertheless the only acceptable basis for testing this hypothesis is empirical data. (8)

The third mechanism of trauma is by acoustically mediated bubble growth/formation. One mechanism of tissue damage is sonic-induced bubble formation or growth in tissues that are supersaturated with nitrogen (or other biologically inert gases used in diving such as helium). The amount of gas dissolved in tissues is a function of dive depth (hydrostatic pressure), dive duration, descent and ascent rates, and the depth at which gas exchange is precluded by alveolar collapse. In humans and some other mammals, especially those breathing compressed gas, sudden decompression causes nitrogen to come out of solution and form bubbles (termed decompression sickness, caisson disease, or the “bends”). Two possible means of bubble growth initiation have been hypothesized; 1) activation of bubble nuclei (microscopic bubbles) that are stabilized within the tissues, and 2) acoustic or mechanical cavitation (see 9,10 for models that have been proposed). This is especially very important since a close cooperation and thereby a sustained subjection to sound waves will be expected in CADDY. During decompression phase of the dive bubble growth might be mediated or enhanced by the corresponding resonant sound frequencies.

2.2.4 EM hazards

The salt water is a very good filter for electromagnetic waves. However, there is still a potential hazard while using LASER for scaling. On the other hand, some diver equipment are reported to fail when subjected to high EM fields, such as the wireless air integration units.

2.2.5 Psychological problems

The existence of the AUV in the vicinity of the diver may impose a threat and reduce the work efficiency. They can also diminish the attention span of the divers. We believe that this will be overcome to a great extent over the time by habituation. It is also true that even the presence of a human "new" buddy will diminish the task efficiency of the diver while compared to the "usual dive buddy".

3 FORMAL RISK ASSESMENT

A formal risk assessment needs to be carried out before any AUV operation involving diver intervention. There are various methods: A simplified method is proposed for the CADDY project:

The first step is the description of hazards specific to the dive site. A general hazard identification induced because of the use of AUV's is described in the previous section:

The second step is to quantify the associated risks – An attempt to determine significance, usually as a product of probability x exposure x consequence, so along the following lines:

Probability (of an event): ① unlikely ② unusual ③ possible ④ expected ⑤ definite

Exposure (to a hazard):

① rare (>1/yr)

② unusual (≈1/mo)

③ occasional (≈1/wk)

④ frequent (≈1/d)

⑤ continuous

Consequence (severity of outcome):

① noticeable (1st aid)

② significant (minor damage)

③ serious (disruption)

④ severe (close)

⑤ catastrophic (fatal/destruction)

The third step is to deal with them as per the table:

>100	1	Extreme danger
50 – 100	2	Very high: Stop use
20 – 50	3	High: Urgent attention
5 – 20	4	Medium: Attention needed
<5	5	Low: Acceptable risk

The final step will be an attempt to mitigate the risks by taking the following measures:

(1) isolate at source using engineering or technical means (engineer out the exposure or the hazard)

(2) attempt to prevent exposure through administrative means (procedures or training)

(3) protect people or equipment through personal protective equipment, barriers, monitoring equipment (leakage detection for electrical grounding: earth leakage or line isolation monitoring) etc.

(4) And finally by monitoring that our measures are effective either by measuring incidents and near misses, or by monitoring the unsafe environment.

It is advised that a HIRA (Hazard Identification and Risk Assessment) study is accomplished before each AUV operation involving divers.

4 CONCLUSION

4.1 Suggested Mechanical requirements

The divers will be requested to use protective helmets (similar to those of the cyclists and not a real diving helmet such as the Kirby Morgan Superlite Mk17) to prevent head traumas. They will be also required to have a fully redundant gas supply such as a small extra tank and its regulator. Full face masks were also advised for greater protection from collision accident.

It is equally possible to have a kill switch activation automatically when the AUV are at a specific distance from the head of the diver.

The propellers or the AUV's should be guarded and the guard integrity needs to be checked before and after each dive.

The handling of an AUV, including its launch and recovery, is essentially a lifting operation and therefore presents a risk of injury to people and equipment. IMCA has developed guidance on lifting, which though designed primarily for subsea lifting operations, is relevant to all offshore lifting operations and generically to lifting operations anywhere. This guidance can be found in IMCA M 187 – *Guidelines for lifting operations.* IMCA S 011 5

4.2 Suggested acoustical requirements

Careful measurements needs to be done before sending the divers in the vicinity of the AUV's while they are communicating with acoustical modems or using SONAR technology for navigation or obstacle avoidance. Although the stated frequency ranges of the ancillary acoustical devices may not be within the dangerous zone for human health, the harmonics or signals improperly filtered to yield lower frequency sound waves may arise.

Prevention of sound pressure damage:
The AUV emitted sound levels should be must lower than the ones causing the tissue damage. The threshold level of acceptance will be simply the minimum frequency and power to start the discomfort in divers. Subjective annoyance and discomfort may occur in some individuals at levels between 75 and 105 dB for the frequencies from 10 kHz to 20 kHz especially if they are tonal in nature. Hearing protection or engineering controls may be needed to prevent subjective effects. Tonal sounds in frequencies below 10 kHz might also need to be reduced to 80 dB. These values assume that human coupling with water or other substrate exists. These thresholds may be raised by 30 dB when there is no possibility that the ultrasound can couple with the body by touching water or some other medium (12).

Prevention of tissue resonance damage:
Human lung resonant frequency of 42 Hz (compared to actual value measured at the surface of 40 Hz). For bottlenose dolphins it predicts 32.3 Hz (vs. 34 Hz measured), and for white whales it predicts 27.4 Hz (vs. 28 Hz measured) (8). Although little evidence exists for the tissue resonance damage at low

power devices such as the ones used in the listed AUV's, the ancillary devices used in AUV's should not emit sounds close to the resonant frequency simply to avoid the discomfort of the diver.

Bubble excitation and decompression management: Doppler and Echo studies needs to be planned while decompressing near sonar and acoustical modems. The initial dives needs to be conducted by carefully increasing the bottom time and depth. It is also advised to stay within the NO - D limits or use the classical methods to reduce the decompression stress (next bottom time, increased conservatism in case of dive computers etc)

4.3 Suggested EM requirements

Whenever scaling LASERs will be used in AUVs, divers must be warned about the impact and should get use personal protective eye glasses. Divers should not use hoseless air integration devices to prevent the masking effect of any high EM source (Motors, strobe etc).

4.4 Suggested Electricity Requirements

In order to gain the diving industry recognition all AUV's and ASD's need to comply with the IMCA code of practice (11). The power on most commercially operated AUVs comes from polymer-based rechargeable lithium-ion batteries, from fuel cells, or a combination of both. Fuel cells and lithium batteries are both classed as dangerous goods and as such, special requirements should be in place to address their handling, storage, transportation and ultimate disposal. Fuel cell systems also introduce chemical handling issues which require specialist training and very robust handling procedures. Appropriate procedures for the handling and charging of power sources, developed in partnership with manufacturers, should be in place.

4.5 Suggestions on Kill Switch

A **kill switch**, also known as an **emergency stop** or **e-stop**, is a safety mechanism used to shut off a device in an emergency situation in which it cannot be shut down in the usual manner. Unlike a normal shut-down switch/procedure, which shuts down all systems in an orderly fashion and turns the machine off without damaging it, a kill switch is designed and configured to *a*) completely and as quickly as possible abort the operation, even if this damages equipment and *b*) be operable in a manner that is quick, simple (so that even a panicking user with impaired executive function can operate it), and, usually, *c*) be obvious even to an untrained operator or a bystander.

Kill switches are featured especially often as part of mechanisms whose normal operation or foreseeable misuse may cause injury or death; designers who include such switches consider damage to or destruction of the mechanism to be an acceptable cost of preventing that injury or death.

Each AUV must be equipped with at least two of the following redundant set of kill switches: mechanical, mechanical, electromagnetic, light based or acoustic.

Upon stopping, the AUV must not release any weight to return to the surface (this method can be intended to recover the AUV). Ballast release might cause a collision with the stand by divers that are arriving from the surface in case of an accident.

4.5.1 Mechanical Kill Switch

Preferably, more than one mechanical kill switch needs to be placed along the hull of the AUV in order to provide ease of access. A removable barrier or other protection against accidental activation (*e.g.*, a plastic cover that must be lifted) can be used BEFORE the AUV is deployed, but these barriers should not be present while operating underwater.

4.5.2 Magnetic Kill Switch

To avoid the complications of handling the mechanical kill switches, magnetic kill switches might be placed on the hull at specific locations. The place of the switches should be tagged carefully and they can be activated by the magnets that are placed at the tip of the diver's gloves.

4.5.3 EM Kill Switch

The electromagnetic waves can travel couple of meters underwater depending on the power output, salinity and the frequency. The kill switch might be activated by an EM transmitter held by the diver. The AUV's must be equipped with the receiver coils that will detect the kill switch signal. The best EM kill switch configuration will be a transmitter that is placed on the helmet of the diver and activates the receiver coil of the AUV when it is at the proximity of the head.

4.5.4 Acoustic Kill Switch

Specific coding for acoustical "kill" signal can be used efficiently both by the divers and the topside operators offering a big distance advantage.

4.6 Suggested Human Resources Requirements

Advance planning is the ultimate cure to prevent accidents. For any AUV operation that involves diver in water, the dive plan including the primary purpose of the dive, the depth and bottom time limits should be defined in writing at least 15 days before the dives and should be relayed to the diving supervisor. All AUVS must have appointed operator personnel. The duties of the AUV staff should be clearly defined in writing and must be communicated to the diving team. On the other hand, the divers needs to have proper training levels and fitness to dive medical certification as described in the Appendix. Dive team manning levels must respect the numbers listed in the Appendix.

The dives should be conducted according to the Safety Manual Provided as Appendix to this communication. The final detailed dive plan should be discussed in detail with the Diving Supervisor, Diving Safety Officer, Divers (including Stand by Divers and tenders), boat personnel (if any), AUV support staff before any operation.

To measure the efficiency of the divers a series of the psychomotor performance tests using the Psychology Experiment Building Language (PEBL) software version 0.13. Thereby, it will be possible to measure if they feel comfortable while working next to the AUVs.

4.7 Communication: No Comms-No Diving

Two way communication between divers, diver-supervisor, supervisor-AUV operators must be established. Through water communication is not preferred unless the visibility is adequate or a tether is provided with tender personnel trained on life line signals. The communication between the diver and AUV might be more efficient if a confirmation signal is mandatory from the diver side. As an example:

- Diver gives the sign of "Come closer" (Each distance step can be quantized to 1 m and accurate distance can be given by multiple commands).
- AUV displays "I come closer"
- Diver confirms by
a/ a strobe light
b/ a specific acoustical "I confirm" signal

It should be necessary that the diver have an "abort mission" confirmation as a negation to the misinterpreted command or in order to abort the command in action

Diver gives a negative answer.
a/ a series of strobe light (say 2, can be achieved by using a slave stobe)
b/ a specific acoustical "NO" signal

4.8 Pre Dive Checks

All AUV operators must prepare a written checklist and perform it before the start of the operation. The diving supervisor on the other hand must perform the checks required before each dive according to the safety manual given in the appendix. Post dive checks are also useful for continuous improvements as well as post dive debrief meetings.
Practising the kill switch feature should be in priority. In case of activation by the diver, each member of the dive team should demonstrate the skill to use the kill switch efficiently. Also the measurement of the sound frequencies and power prior to deploying the divers must constitute the crucial parts of the "CADDY Check".

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APPENDIX

Sample DAN HIRA (Hazard Identification and Risk Assessment) Report

1.

Divers Alert Network

Hazard Identification and Risk Assessment

Facility Name

DAN HIRA

2. General

An on-site hazard identification and risk assessment of ……, located in ……, was performed in response to a request from Divers Alert Network, as part of the HIRA programme.

This report, which documents the actual process that was followed, is intended to serve as a management review and internal audit tool, and to assure safety of the facility and its operations. It is not intended to suggest compliance or accreditation with any external document or authority.

3. Scope

The HIRA and this resulting detailed report apply to diving operators and the associated facilities that are used to provide diving services to clients.

The scope is focussed purely on the technical, operational and safety aspects related to these facilities.

4. Purpose

The primary purpose of this report is to provide the owner with a current and documented step-by-step assessment of the safety level of the facility, in order to provide a measure of compliance with the minimum technical safety requirements when providing diving services to clients.

In preparation for further safety audits and external review, this process has been undertaken in writing, specifically as it relates to the assessment of actual or likely risks and the compliance or non-compliance with the minimum applicable requirements.

It is also intended to provide guidance and recommendations for the enhancement of facility safety and improvement of certain operational aspects, as well as suggestions for possible future facility upgrade.

5. Basis

The basis of the process is an analysis of the risks that are inherent to:

- Administrative and managerial processes
- The provision of appropriate breathing gases to clients
- The operation of transport vehicles
- The operation of boats and diving vessels
- The use and application of diving equipment
- Emergency responses and management, and
- Staff health and safety

Each classified risk has been considered in the light of actual, quantifiable risks, and this facility has been assessed for compliance with specified requirements that either mitigate, remove or acceptably contain such potentially hazardous situations.

6. Brief description of the facility

…… is situated in **……** and provides diving training and services in the area. **Description of the facility.**

7. Statutory regulations and international guidelines

This report does not supersede the requirement for compliance with any statutory or regulatory instruments of **……**, and any such statutes and referenced regulations take legal precedence over the findings and conclusions contained in this report.

…… statutes have been identified and incorporated, and in addition, industry-proven guidelines have been used to facilitate the assessment of the minimum levels of safety.

For reference purposes, the following additional documents have been consulted in the compilation of this report. Please note, however, that this report does not claim to comply either in part, or as a whole, with any or all of these documents.

8. Statutory documents

- Change to accommodate specific area.
  Occupational Health and Safety Act of 1994 together with the applicable Regulations such as Noise Regulations, Hazardous Chemical Substances, etc.
- Compensation for Occupational Injuries and Diseases Act
- National Conservation Act
- Employment Equity Act
- Labour Relations Act
- SAMSA Directives applicable to boating and diving operations

9. Other guidance documents

- Compressed Gas Association (CGA), Handbook of Compressed Gases, latest edition.
- Compressed Gas Association (CGA), G-7.1-2011, Commodity Specification for Air, 2011

- Compressed Gas Association (CGA), Cleaning Equipment for Oxygen Service, G-41, 1996.
- American Society for Testing and Materials (ASTM), Standard Practice for Cleaning Methods and Cleanliness Levels for Materials and Equipment Used in Oxygen Enriched Environments, G-93, 1996.
- USCG (United States Coast Guard) Marine Safety Advisory, Recommendations for Recreational Diving Operations Occurring from Commercial Passenger Vehicles, Advisory 01-12.

10. Definition of terms

The following key terms are defined in the context of this report:

Competent- means having the knowledge, training and experience specific to the work or task being performed: Provided that where appropriate qualifications and training are registered in terms of the provisions of any legislation, these qualifications and training shall be deemed to be the required qualifications and training; declared competent by an accredited assessor or institution

Responsible person - means the person bearing the overall responsibility for all equipment, operations, maintenance and safety-related matters.

11. Explanatory notes

Where a "conforming comment" appears, this indicates whether measures are in place or need to be put in place for a classified or identified risk. This comment is provided as guidance for different issues assessed, according to the following table:

Conforms	Explanation
Yes	Compliant; implying either full compliance or applicable compliance.
Noted	Compliant within the scope of the clarification notes provided at the end of each section, or as commented within the text of the explanation of the risk.
N/A	Not Applicable within the scope of this assessment or this facility, i.e. not required or not used.
N/R	Not Required as this requirement has been addressed or included elsewhere.
No	Not-Compliant.
F/A	For Attention – Facility has been notified and attention will be given. It remains the responsibility of the responsible person to follow-up and to action for rectification.

The interpretation or choice allowed for applies either (1) due to the type or nature of the facility; or (2) where local authorities may allow a degree of qualified discretion; or (3) where the *responsible person* should determine whether this is an applicable risk.

12. The risk assessment process

The following method was used to determine the degree of compliance of the facility.

Enter details about observation period and participation in dive activities.

13. Disclaimer

While this document is consistent with both local regulations and current international safety guidelines, no responsibility can be assumed by the assessor for any injuries or damage of any nature whatsoever, as a result of product failure, negligence, or from the application of any recommendations or ideas contained in this report. Although every care has been taken to ensure the accuracy and validity of the information extracted from other sources, no guarantee or warranty can be provided as to the original information. Any statement of compliance with any aspect of this document shall remain the sole responsibility of the issuer of the statement and shall not be attributed to the author.

14. Reservation of rights

Staff Health and Safety		
Risk	**Explanation**	**Compliance**
Copy of legislation	Copies of the relevant legislation applicable to the operation are available and up to date on file.	No
H&S policy	The company has a written Health & Safety policy, containing the elements prescribed in legislation.	No
Registration with compensation commissioner	The company has registered its employees with the compensation commissioner.	No
Dive Accident Insurance	All diving personnel have current dive accident insurance (e.g. DAN; PADI; etc.).	No
Hazard identification	Hazards to staff health and safety are identified in a structured manner and available in a written format.	No
Health and safety representatives	If more than [20] employees, then health and safety representatives are appointed in accordance with the relevant health and safety legislation.	No
Medical surveillance	Staff members are subjected to a medical surveillance program, which covers the following aspects: • Fitness for work evaluation (including diving medical examinations for diving staff) • Monitoring of exposures • Monitoring for occupational diseases Note: The common occupational diseases that should be considered are included below.	No
Sunburn	Staff are adequately protected from sunburn. This includes policies to ensure that they will not overexpose themselves to excessive UV radiation.	No
Noise screening	Noise areas are identified and clearly demarcated.	No
Noise protection	A hearing conservation program is in place, which includes the following: • Training and education about noise & its effects • Issuing of hearing protection • No entering noise zones without PPE	No
Screening for hearing loss	All employees working in noise zones (e.g. compressor operators) are subjected to screening by means of audiograms.	No
Exposure to chemical substances	Possible exposure to chemical substances is identified and managed.	No
Screening of skin	Persons exposed to chemical substances are medically screened for effects on the skin. Persons inhaling chemical substances are screened by occupational health personnel.	No
Control of hyperbaric exposures	A system is in place to prevent employees from suffering decompression-related diseases. (Example: One diving-free day after a maximum of three days' diving).	Yes
Notes & Recommendations		
Hazard	It is recommended that documented procedures are recorded on file and updated on a	

identification	regular basis.
Sunburn	Verbal daily reminders are set but it is unclear if there are written policies in place.
Screening for hearing loss	This risk mitigation strategy will ensure that the employer is pro-actively managing the health of staff and will be able to avoid both health and legal consequences.
Screening of skin & inhalation risks	It is highly recommended that persons exposed or that inhaled chemical substances seek medical attention and be screened by occupational health personnel.
Copy of legislation	It is recommended that local legislation be reviewed and complied with, as applicable.
H&S policy	Not known: dive manager to follow up with the resort management.
Registration with compensation commissioner	Not know: dive manager to follow up with the resort management with regard to Insurance benefits.
Dive Accident Insurance	Most of the dive masters and instructors have DAN cover. It is recommended that this be made a policy by management.
Health and safety representatives	The Mozambican staff has limited representation via the Mozambican authorities, but nothing is in place for the expat staff members. Dive manager to follow up with the resort management.
Exposure to chemical substances	It is recommended that the employer identify whether any harmful substances are in use and if so, that proper management and protection measures are in place. It is reported that System 500® (an acid) is used for cleaning purposes when doing repairs and maintenance. No Material Safety Data Sheet is available on file and no personal protective equipment e.g. gloves, goggles, aprons; are worn when working with the chemical. It is suggested that the MSDS be obtained to familiarize the employer and staff with the chemical properties as well as possible risks when using this chemical and which precautionary measures should be taken. It is reported that System 620® (an acid from Hudson Chemicals) is used for cleaning purposes when doing repairs and maintenance. No Material Safety Data Sheet was available on file and no personal protective equipment e.g. gloves, goggles, aprons; are worn when working with the chemical. MSDS was obtained while doing assessment and it was advised that the suggested precautionary measures should be taken.
Medical surveillance	A biannual recreational dive medical is advised. Screening for hearing loss if working in noise area is advised.
Noise protection	It is recommended to implement an effective hearing conservation program to educate employees about the risk of noise pollution and how to preset injury over time. An effective hearing conservation program can prevent hearing loss, improve employee morale and a general feeling of well-being, increase quality of production, and reduce the incidence of stress-related disease.

Client Health and Safety

Risk	Explanation	Compliance
Health questionnaire	A policy is enforced to ensure that all clients who wish to dive with the operator are required to complete a confidential, comprehensive health questionnaire prior to being allowed to dive. Any abnormalities are communicated to the operator's resident diving doctor or to the DAN hotline for advice.	No
Compulsory	All clients are required to provide proof of medical	No

medical insurance	insurance. Any clients who does not have medical insurance are required to obtain dive accident insurance. *Note: other travel insurance packages normally exclude diving activities from cover.*	
Medical insurance details	The medical insurance details of each client are recorded as part of the registration process. This includes the following: • Primary medical insurer (irrespective of whether DAN membership is in place), membership number, cover option, main member ID. • DAN membership number.	No
Emergency contact details	All clients are required to provide contact details of a reliable person to contact in case of an emergency.	No
Declaration of indemnity	An indemnity form is signed by clients, which indemnifies the operator against injuries and/ or losses.	No
Indemnity insurance	The operator has adequate indemnity insurance and liability cover in place.	No
Dive Certification/ Logbook	Diver certification cards are checked and logbook completion encouraged.	No
Restricted access	Clients are not allowed to enter restricted areas (e.g. compressor rooms, etc.)	No
Cancellation of open water dives	A written policy is in place and enforced to cancel open water dives based on specific identified risks, e.g. sea state; hazardous marine life (like blue-bottles), non-availability of oxygen (as when used during the previous dives), etc. Each such incident is logged and available for audit.	No
Notes & Recommendations		
Health questionnaire	Only scuba reviews & clients wanting to complete a scuba course are required to complete a medical questionnaire. This doesn't comply with the MARITIMO document Decree 44/2006 of 29 November REGULATIONS ON AMATEUR DIVING, CHAPTER III Admission and Certification, SECTION I Admission and Certification, Article 10 Amateur divers.	
Compulsory medical insurance	Divers are strongly recommended to ensure they have adequate dive cover prior to their dive trip.	
Cancellation of open water dives	Cancellation policies are in place but it was unclear if records are kept. It is recommended that a policy be put in place and implemented in order to better manage cancellations, as well as preventing clients from putting the business under pressure should conditions be unsafe for diving. Financial commitments need pro-active management lest they become contract breach issues.	
Emergency contact details	This recommendation is made to alleviate the stress of trying to retrieve this information during any actual emergency situation and is regarded as industry-standard.	
Indemnity insurance	Not known: dive manager to follow up with the resort management.	
Medical insurance details	It is recommended that primary insurance details (e.g. medical aid) and/ or DAN membership numbers are recorded. This will assist in the event of a dive unjury.	

Staff Training and Certification		
Risk	**Explanation**	**Compliance**
Instructor trainer	An in-date instructor-trainer is available on site.	No
Copies of training &certification	Copies of the relevant documents are available and up to date on file.	No
Courses represented	All the following training courses are available and could be taught on site: • First Aid • Basic Life Support • Oxygen • Neurological examination • Automated External Defibrillation	No
Notes & Recommendations		
Instructor trainer	Only instructors are on site but during busy dive seasons additional dive staff are available to assist; however it was unclear what in-date qualifications checks are done.	
Courses represented	No AED trained staff.	

Training Pool Area		
Risk	**Explanation**	**Compliance**
Sun protection	The training pool area has sufficient shaded areas to protect against excessive sun exposure. Employees and customers are actively encouraged to wear sunscreen – signage to this effect is preferred	No
Slip & fall risk	The area flooring has sufficient friction to protect against slips and falls – especially when wet.	No
Drowning barriers	Access to the training pool area is restricted whenever the training pool is not in use by means of a physical barrier (fence) or safety netting.	No
Pool hygiene	The training pool is subjected to a logged hygiene and cleaning protocol. This includes the addition of chemical substances (e.g. chlorine).	No
Oxygen available	Oxygen is available next to the poolside whenever pool training is conducted.	No
First aid kit	A first aid kit is available in reasonable proximity to the pool training area in order to deal with minor cuts and injuries.	No
PBT & AGE protocol	A protocol for the management of pulmonary barotraumas and its consequences (e.g. pneumothorax, arterial gas embolism, etc.) is available and known by all personnel involved in using the training pool.	No
Supervision	The training pool is only used under the supervision of a person, trained in the specific diving procedures and trained in dealing with emergencies associated with its use.	No
Instructor: student ratios	The student: instructor ratio does not exceed 1:6 whenever the pool is used for novice divers.	No
Water ingress &	Safe ingress and egress procedures are used in the	No

egress	training pool, e.g. ladder will not cause finger injuries, bench used to practice back-roll.	
Change room	A change room is available and is safe (e.g. no-slip floors) and hygienic.	No
Ablution facilities	Hygienic ablution facilities are available – for each gender.	No
Pre-dive briefing	A pre-dive briefing is performed before use of the training pool. The pre-dive briefing contains at least the following elements: • Activities planned • Safe ingress & egress • Location of emergency equipment • Avoidance of breath-holding & risk of barotraumas	No
Buddy checks	Buddy checks are performed prior to each dive, specifically covering the following: • BCD functional • Weight-belt • Fins • Mask • Cylinder open and regulator functional	No
Post-dive briefing	A post-dive briefing is performed, discussing problems experienced during the training session.	No
Notes & Recommendations		
Pool hygiene	There is a clear hygiene policy in place but it is unclear whether this is a written policy and whether a log is kept.	
PBT & AGE protocol	All staff know how to manage this risk but it is unclear if a written policy is in place.	
Water ingress & egress	It is recommended to provide a ladder or steps to safety enter and exit the pool.	
Drowning barriers	This recommendation is made to prevent any unnecessary accidents from happening during scuba training or when there is not supervision available thereafter.	
Oxygen available	It is recommended that oxygen be available on site in case of a dive injury.	
First aid kit	It is recommended that a first aid kit be available on site in case of a dive injury.	
Training Room		
Risk	**Explanation**	**Compliance**
Table ergonomics	Tables are at an ergonomic height – sufficient space available for each student.	No
Electrical supply	The electrical supply to the area and appliances is safe and neat.	No
Lighting	Lighting is adequate and is likely to conform to a standard of 200 Lux.	No
Ventilation	Adequate ventilation is provided (if natural ventilation is used, a policy should be in place to ensure the windows, etc. remain open during teaching.	No
Temperature	The training room has a comfortable temperature. Air conditioning is provided where necessary.	No
Emergency exit	The facility can be easily evacuated in case of an	No

	emergency (e.g. fire).	
Ablution facilities	Clean and hygienic ablution facilities are available to students making use of the facility. Separate facilities are provided for males and females.	No
Breaks	A system is implemented to ensure adequate rest breaks are available during training.	No
Fire prevention & extinguishing	Fire hazards are identified and actively managed. Adequate fire-fighting measures are in place. Fire extinguisher is in-date.	No
Notes & Recommendations		
Lighting	During the day there is sufficient lighting but at night the classroom lights don't conform to the 200 lux standard	
Fire prevention & extinguishing	Fire hose and Fire Strike extinguishers are used. Fire extinguisher sign present but no fire extinguisher cylinder present)	
Table ergonomics	It is recommended to provide the appropriate seating and tables for students to avoid minimize any physical discomfort.	
Emergency exit	It is recommended to provide an exit for emergencies such as a fire: the combined use of regular and special exits allows for faster evacuation, while it also provides an alternative if the route to the regular exit is blocked by fire, etc.	
Dive shop		
Risk	**Explanation**	**Compliance**
Friendly staff	The facility staff are friendly and make visitors feel welcome.	No
Site and surroundings information	Information is provided regarding the site and surroundings (e.g. tourist information brochures).	No
Dive sites	A file is kept with information regarding the dive sites.	No
Emergency procedures	A file containing the emergency procedures of the company is available in the dive shop.	No
Policies	A file containing the normal operating procedures of the company is available in the dive shop.	No
Work station	A comfortable, ergonomic work area with sufficient space is provided.	No
Electrical supply	The electrical supply to the area and appliances is safe and neat.	No
Lighting	The dive shop is adequately lit – to conform to a standard of 100 Lux.	No
Ventilation	Adequate ventilation is provided in the shop.	No
Temperature	A comfortable temperature is maintained in the dive shop and use is made of an air conditioning system if needed.	No
Emergency contact numbers	Emergency contact numbers are clearly displayed in the shop – including the following: • The police • The ambulance • Nearest medical facility • Nearest hospital • Divers Alert Network • Fire brigade • Owner or delegate	No

	The information should also be visible when the shop is closed (e.g. in the window).	
MSCC information	The operator has a system in place by which they ensure that the emergency details (including availability and contact numbers of local health providers) remain up-to-date. This can be in accordance with the IDAN MSCC (Medical Services Control Centre).	No
Voice message	A voice message is recorded on a voice recorder (e.g. after hours) which contains emergency contact numbers and information.	No
Clean and unobstructed space	The shop (including storage areas) is kept clean and unobstructed.	No
Non-slippery surfaces	The shop flooring surface is made of a material that provides sufficient friction to prevent slips and falls.	No
Emergency exit	Emergency exit from the facility (e.g. in case of fire) is available and unobstructed.	No
Fire prevention & extinguishing	Fire hazards are identified and actively managed. Adequate fire-fighting measures are in place. Fire extinguishers are in date.	No
Security & alarms	A security system and measures are in place, actively enforced, in working condition and tested on a regular basis.	No
Notes & Recommendations		
Emergency exit	It is recommended that an emergency exit be added in case of a fire or other life threatening emergency.	
Fire prevention & extinguishing	Fire hose and Fire Strike extinguishers are used. Fire extinguisher sign present but no fire extinguisher cylinder present.	
Dive sites	It is recommended that detailed records of all dive sites be maintained on file.	
Security & alarms	It is recommended that appropriate security measures be put in place to help avoid unnecessary break-ins and damage to property.	
Diving boat operations		
Risk	**Explanation**	**Compliance**
SAMSA registration	The dive boat is registered with EDA & UE and contains the regulated equipment for normal and emergency operations. Specific requirements for night diving are complied with.	No
Skipper trained Skipper certified Skipper appointed	Well-trained and certified personnel (specific to diving operations) provide this service to divers.	No
Training and certification information on file	The skipper training and certification information is kept on file – indicating that this is actively managed and controlled.	No
Alcohol & drug policy	An alcohol and drug policy exists, which specifically covers boat skippers, including how this will be evaluated and tested and how it will be managed in practice.	No

Slips & falls	The risk of slipping and falling on the dive boat is minimized by either engineering controls (e.g. friction-surfaces); administrative controls (e.g. prohibiting specific types of shoes) or personal protective equipment (e.g. providing non-slip shoes). Oil/ fuel leakage is cleaned & washed out prior to divers arriving.	No
Safety cut-out switch	A safety cut-out switch is in use that would ensure the boat engines will cut out in the event of the skipper falling overboard.	No
Pre-dive boat preparation	Checklists are used to ensure the dive boat is ready before divers arrive. The checklists contain the following information (as applicable): • The boat is clean (e.g. oil/ fuel leakage) • Sufficient fuel is loaded (including emergency supply) • Correct working of GPS/ communication system/ radar • Emergency & first aid equipment loaded • Tool kit on board (plug spanner, adjustable spanner, pliers, spark plug) • Drinking water loaded • Diving spares on boat • Boat plugs are fitted	No
First aid equipment	First aid equipment is available to deal with minor cuts and bruises.	No
First aid for marine life	First aid equipment is available to deal with marine life injuries expected in the area (e.g. acetic acid/ vinegar, etc).	No
Location of first aid equipment	The location of first aid equipment should be clearly indicated, preferably with the international sign (green cross with a white background).	No
Control of first aid equipment	First aid materials are protected against the elements (e.g. in a waterproof casing). The contents of first aid boxes are controlled by means of a specific system (e.g. checklists).	No
Oxygen kit	An oxygen kit should be available on the dive boat to enable immediate management of a confirmed or suspected diving injury. The oxygen kit contains sufficient oxygen to allow supply of oxygen for at least one, but preferably two divers for the duration of the expected longest boat trip to an additional source of oxygen.	No
Control of oxygen kit	The oxygen kit is in-date. The oxygen kit is protected against the elements. The oxygen kit is controlled (a single person – usually the skipper) is responsible to ensure that the oxygen kit is on the boat. The oxygen kit is subjected to a logged, regular maintenance schedule and remains in a good state	No

	of repair.	
Rehydration fluids	Isotonic oral rehydration fluids are available on the boat.	No
Rehydration policies	Skippers and dive leaders know how to apply rehydration fluids in the case of decompression illness.	No
Diving spares	Spare equipment is available on the dive boat, especially the following: • Marker buoys • Spare regulator & mask • Spare weight-belt/weights • O-ring kit	No
Equipment secured	The equipment on the dive boat is secured – ensuring that equipment will not fall onto (and injure) persons and also prevent equipment losses. All loose equipment is secured and no person is allowed to hold equipment (e.g. diving torch/ camera) during the launch or beaching.	No
Pre-dive briefing	A pre-dive briefing is performed before each dive. The pre-dive briefing contains at least the following elements: • Communication, hand signals to be used • Emergency procedures (lost diver, buddy separation, out of air) • Location of emergency equipment • The dive site (description, name, specific risks • Sea conditions (visibility) • Dive leader roles • Buddy pairs • Diver recall system • Hazardous marine life • The dive (depth, time, safety stop, suggested air reserves)	No
Boat briefing	A boat-briefing is performed by the skipper before the dive, containing at least the following elements: • General boating safety • Location of emergency equipment • Positions on the boat • Securing oneself (feet straps, etc.) • Prohibition against non-staff members standing • Propeller safety • Diver recall • Getting safely into the boat after the dive	No
Positioning on boat	Divers are positioned on the boat, taking into consideration: • Each diver is positioned close to his/ her equipment • Each diver is next to his/ her buddy	No
Kitting up	The boat crew assist divers in kitting up.	No
Self &/ Buddy checks	Buddy-checks are performed before the dive: • BCD, power inflator functional	No

	• All straps secured • Fins on • Weight-belt secured, but in a position in • Air open	
Buddy checks controlled	The instructor/ divemaster ensures that buddy checks are performed by all divers and they report back that all checks are correct.	No
Diver recall	A system is in place by which divers are recalled to the surface (e.g. due to deteriorating weather/ emergency/ etc.).	No
Boat engine warm-up	Before launching the boat, the engines are checked to ensure normal functioning. The engines are adequately warmed up to prevent engine cut-out in the surf.	No
Boat launching	Procedures are in place to ensure that divers are cleared from the motors at all times during the launch. Launching is done in a way to ensure no person is injured. The following near-miss statistics are monitored: • Persons falling or slipping during mounting • Bumps and bruises during mounting • Any person present behind the boat in the surf • Any person falling off the boat • Capsizing These statistics are analysed and procedures put in place to reduce such occurrences.	No
Water ingress	Ingress in the water should be coordinated, to ensure divers don't fall on or injure each other. Entanglement is actively prevented (e.g. ensuring an octo does not entangle with ropes on the boat)	No
Diver counts	A system is in place to ensure that the same number of divers are on the boat after the dive (e.g. Diver ID System). In densely dived areas, divers may join another group and surface with them. A system is in place to inform the original boat of divers joining other groups. This means that divers are informed beforehand which group they have dived with.	No
Surface supervision	The skipper monitors the position of the buoy and diver bubbles to determine current speed and to ensure he/ she is clear from the area where the divers are likely to surface.	No
Decompression procedures	A diving computer is available for each person and every person not having a diving computer has a functional personal depth gauge and a means of keeping time under water (e.g. someone who will monitor maximum dive time).	No
A post-dive briefing is performed	The instructor/ dive master performs a post-dive briefing immediately after reaching the shore and this is performed after each dive.	No

	The post-dive briefing contains at least the following elements: • No flying for a specific time • No driving over high mountain passes • Implications for repetitive dives • Need for adequate rehydration • No hot showers for a specified time • DCI symptoms & not to ignore minor symptoms (specific enquiry is made whether someone has any symptoms) • Emergency contact numbers, location of emergency facilities Consideration should be given to providing divers with a card/ piece of paper with the important information.	
Bends-watch	A bends-watch is enforced whenever no-decompression limits are exceeded.	No
Instructor	An instructor (and assistant instructors if applicable) is present with each dive whenever students are diving. Instructor: Student ratios are appropriate.	No
Dive Master	Each diving group not containing students is led by a dive-master who is familiar with the dive site. Dive master: clients ratio is appropriate (recommend 1:5; max 1:10).	No
Propeller safety	Engineering controls (e.g. propeller guards) or administrative controls (e.g. standard procedures) are in place to prevent propeller injuries.	No
Communications	Communication equipment and back-up communication equipment is available and in a working condition to allow communication with the shore/ beach control unit. Communication equipment and back-up communication equipment is available and in a working condition to allow communication with medical personnel (e.g. DAN). Contact details are available in writing.	No
Snorkeling procedures	Snorkeling (e.g. with whale-shark) after the dive is controlled and divers are briefed to remain on the surface and not to perform breath-hold dives.	No
Dive accident management	A written, workable and drilled emergency plan is in place and known by all staff.	No
Lost diver procedures	A written procedure, known to all staff members is in place to deal with lost divers.	No
Approach after the dive	Divers should usually be split in two groups during the approach The approach should be into the wind.	No
Equipment removal	Divers' equipment is removed by the skipper (weight-belt first), to avoid divers straining/ heavy lifting after the dive.	No
Notes & Recommendations		
Alcohol & drug	No written policy in place but a simple smell & behavior test is done to determine any form	

policy	of intoxication.
First aid for marine life	This recommendation is made to ensure that the diving staff are prepared to deal with marine life injuries expected in the area.
Control of first aid equipment	It was not clear if there is a first aid kit checklist & replacement policy in place.
Control of oxygen kit	It was unclear if there is a maintenance logging system in place.
Rehydration fluids	Only water as far as was stated on the date of the assessment.
Diving spares	It is recommended that a spare regulator be kept on board a dive boat in case it is needed for a client of staff member.
Boat Briefing	Location of emergency equipment not mentioned in briefing. Propeller safety not mentioned in briefing.
Decompression procedures	It is recommended that each dives has a means of keeping track of time underwater to monitor dive times and limits in an effort to avoid dive injuries.
A post-dive briefing is performed	It is recommended that divers are provided with the necessary information to avoid any post dive injuries.
Snorkeling procedures	Snorkeling procedures & briefings are in place but there is no mention of not performing breath-hold diving.

Compressor and tank filling area

Risk	Explanation	Compliance
Electrical supply	The electrical supply to the compressors and the tank filling area is safe	No
Safety shoes	The compressor operator is provided with safety shoes and wearing thereof is enforced	No
Restricted access	Access to the compressor and tank filling area is restricted to the compressor operator. No other employees or members of the public are allowed to enter the compressor/ tank filling area.	No
Machine guards	All moving/ rotating machine parts are adequately guarded (e.g. compressor belts).	Yes
Rails	All elevated areas and steps have rails to prevent falls	No
Competent personnel	Compressor operators and filling station operators and gas blending/ mixing operators are comprehensively trained, certified and competent. They are formally appointed in the position and assigned specific responsibilities.	No
Hearing protection	Compressor operators are provided with hearing protection and the wearing thereof is enforced. *Note: See also the occupational health requirements (hearing tests, etc.)*	No
In date cylinders	All cylinders are in date and subjected to a logged maintenance schedule which includes visual inspection at least annually and hydrostatic testing every four years. Aluminium cylinders older than ten years are subjected to annual visual and hydrostatic testing. Cylinders of clients are not filled unless they are in	No

	date (visual and hydrostatic testing)	
Cylinder storage	Cylinders are stored securely (e.g. by chain or rack) to prevent falling over.	No
Cylinder top-ups	Client cylinders are never topped up, but all the contents are emptied before filling their cylinders	No
Number of cylinder fills	The number of cylinder fills are logged and this information is readily available	No
Air filtering	The compressed air is filtered through a system which removes the following substances: • A particulate filter is fitted to the intake • A chemical filter (mol-sieve/ activated charcoal/ activated alumina) • If an internal combustion prime mover is used, a catalytic filter element is used (e.g. hopcalite) to eliminate CO • Particulates • Water separation: A water separator is used and water is preferably drained automatically. If manually, an auditable quality control system is in place • Double filtration (additional oil-absorbent) if oxygen compatibility is needed (e.g. nitrox fills) • An additional drying element is used if 300Bar fills are provided	No
Filter changes	Filters are changed at regular intervals and the filter changes are logged	No
Gauges	It is recommended that dry, oxygen-clean and oil-free identified gauges are used for any oxygen-enriched gas pressure indicators. **Pressure gauges may develop fatigue cracks over a period of time, allowing glycerin, used to damp the gauge needle from compressor vibrations, to seep into the piping system. Glycerin is a known fuel source in oxygen-related fires.**	No
Checks	A checklist is used to perform critical checks before and after using compressors and filling stations	No
Compressor maintenance	The compressors are serviced in accordance with a set schedule by the manufacturer's agent or a person specifically trained and competent to do so	No
Compressor maintenance log	A separate log is kept of all maintenance activities performed on each compressor	No
Compressor attendance	No compressor may be left unattended while in operation	No
Air intake	Compressor air intakes are placed in a safe location, where contamination is not possible. The filling station is not located in close proximity to a parking lot or an area where there is significant vehicle movement	No
Air intake notice	Notices are displayed indicating the position of air intakes and prohibition of keeping motors running, etc.	No
Air intake	Public access to the air intake is restricted, either	No

security	through physical barriers or by ensuring the intake is placed at a height.	
Air quality system	A documented air quality system is in place and is available for audit-purposes. The system indicates the frequency of specific actions to ensure the quality of breathing air, e.g. periodic testing for contaminants, logged filter changes, etc. Confirmation of the effectiveness of these actions is provided.	No
Compressed air bank	The compressed air bank is in date	No
Client complaints	Client complaints about air fills and air quality are logged in a complaints log and each incident is fully investigated by a competent person and a report is generated with specific recommendations for action	No
Filling of nitrox or trimix cylinders	Nitrox and/ or trimix cylinders are never filled with normal air, unless specifically marked and the air is compatible with oxygen	No
Oxygen handling	Oxygen is handled in a safe manner and hydrocarbon contamination is prevented	No
Fire safety	Fire hazards are identified and actively managed. Adequate fire-fighting measures are in place. Consideration is given to installing an overhead sprinkling system in the compressor/ air filling station	No
Environmental pollution and waste management	Industrial waste is disposed of at a recognized and demarcated control area.	No
Notes & Recommendations		
Safety shoes	Recommended that all staff working with equipment that could injure their feet at work be supplied with the correct PPE. Follow-up is required to ensure that the staff comply with this policy.	
Competent personnel	All compressor personnel should have the necessary training and certifications as compressor operators to reduce the liability risk to the company.	
Cylinder storage	Cylinders need to be secured to avoid any potential damage should the cylinders fall over – this could lead to serious damage and injuries.	
Checks	It is recommended to complete the necessary pre & post compressor checks to identify problems in advance and to correct them to avoid unnecessary injuries or compressor failure.	
Compressor maintenance	Not known: dive manager to follow up with the resort management and find out who is contracted to do the maintenance on the compressor.	
Compressor maintenance log	It is recommended that all the compressor maintenance activities performed be logged to help indicate when the next service is due, to ensure good performance and to avoid filling cylinders with contaminated air.	
Air intake notice	It is important to clearly indicate to the public and other resort staff where the air intake of the compressor is situated to avoid the compressor intake being exposed to contaminated air.	
Air quality system	It is recommended that the air quality be tested on a regular basis to ensure clean air is being used in cylinders for diving purposes and to avoid diving injuries from occurring.	
Client complaints	It is recommended that all client complaints are recorded and to do the necessary investigations to determine the quality of air used for diving purposes and to take the	

	necessary actions if needed to resolve any issues concerning contaminated air.
Fire safety	There are no adequate fire-fighting measures in place. Petrol is kept in the compressor room which is a major fire hazard.
Environmental pollution and waste management	It is recommended that industrial waste ne disposed of correctly to minimize the environmental impact.
Cylinder top-ups	It is recommended never to top up client cylinders in the event that the air in a client cylinder is already contaminated.
Restricted access	The public has no access to the compressor area but the resort staff not trained as compressor operators can easily access the facility. This area should be a restricted area for trained personnel and signage provided.
Hearing protection	Recommended that all staff working with equipment that could injure their ears at work be supplied with the correct PPE. Follow-up is required to ensure that the staff comply with this policy.

Equipment storage area

Risk	Explanation	Compliance
Lighting	Lighting is adequate.	No
Ventilation	Adequate ventilation is provided.	No
Fall prevention	The equipment is well-secured and falling of equipment is unlikely	No
Sun protection	The diving equipment is protected from exposure to direct sunlight	No
Temperature extremes	The diving equipment is protected from exposure to temperature extremes	No
Infection control	Equipment is adequately cleaned in a hygienic manner to ensure adequate infection control. DVs are washed in a separate basin as wetsuits and other equipment and an antiseptic solution is applied	No
Fire prevention & extinguishing	Fire hazards are identified and actively managed. Adequate fire-fighting measures are in place. Fire extinguisher is in date.	No

Notes & Recommendations	
Fire prevention & extinguishing	Fire hose and fire strike extinguishers are used. Fire extinguisher sign present but no fire extinguisher cylinder present.
Lighting	It is recommended that additional lighting be provided for the storage area.
Ventilation	It is recommended that the ventilation in the storage area be improved to ensure that the dive equipment dries properly.
Infection control	Infection prevention and control measures aim to ensure the protection of those who might be vulnerable to acquiring an infection. The basic principle of infection prevention and control is hygiene therefore it is recommended that DVs are washed in a separate basin as wetsuits and other equipment and an antiseptic solution is applied.

Small Instrument Workshop

Risk	Explanation	Compliance
Instrument workshop	A separate, dedicated small instrument workshop is provided for the servicing of diving equipment (e.g. DV's)	No
Trained personnel	Personnel who are adequately trained will perform repair and maintenance work on diving equipment	No
Restricted	Access to the small instrument workshop is	No

access	restricted to specific individuals only	
Clean and orderly	The small instrument workshop is clean and orderly – there is a specific place for each item and every item is in its place	No
Lighting	Lighting is adequate and is likely to conform to a standard of 200 Lux.	No
Ventilation	Adequate ventilation is provided.	No
Ergonomic workbench	The workbench is at an ergonomic height – usually conforms to the standards of a standing workstation	No
First aid kit	A first aid kit is available in the small instrument workshop. This is clearly marked with the international sign of the green cross on a white background	No
Chemical hazards	Material Safety Data Sheets are available for all chemical substances used in the workshop and compliance with Regulations for Hazardous Chemical Substances are complied with	No
Protective clothing	Adequate protective clothing is provided for the employees working in the workshop, including safety shoes, gloves and overall	No
Hearing protection	Hearing protection is available and the wearing thereof is enforced whenever work which generates noise is performed	No
Electricity	A safe electrical supply is provided, the use of multiple adaptors and extension cords must be avoided and replaced by permanent electrical ducting, cables and sockets.	No
Oxygen safety	Use of oxygen in the area is done safely, taking fire-risk into consideration	No
Fire control	Fire hazards are clearly identified and firefighting measures are provided in proper locations to allow for firefighting. Consideration should be given to an overhead sprinkler system when appropriate.	No
Compressed air	Compressed air is never used to clean surfaces or persons	No
Eating and drinking	Eating, drinking and smoking is prohibited in the small instrument workshop	No
Reporting system	A system is implemented to ensure that any faulty equipment used by staff or clients are reported immediately after the dive. This is logged in a maintenance log, which is available for audit	No
Notes & Recommendations		
Fire control	Fire hose and fire strike extinguishers are used. Fire extinguisher sign present but no fire extinguisher cylinder present.	
Ergonomic workbench	It is recommended that a comfortable work area be provided for the technician to avoid minimize any physical discomfort.	
Instrument workshop	The small instrument workshop is incorporated in the equipment storage area. It is recommended to have a dedicated area available to complete the basic equipment servicing done at the dive centre.	
Trained personnel	It is important that trained personnel service the diving equipment to reduce the liability risk to the company in event of any equipment failure due to poor equipment servicing.	
Chemical	Scalex® is an acid used for cleaning equipment. Instruments or gloves are to be used when	

hazards	working with or handling the product. Goggles to protect eyes against splashes are also recommended.

Vehicle Safety

Risk	Explanation	Compliance
Registration	All vehicles are registered in accordance with the national legislation, including any boat trailers, etc.	No
Roadworthiness	All vehicles remain in a state of roadworthiness	No
Drivers	All drivers of vehicles have a valid driver's license and are at least 25 years of age.	No
Alcohol and drug policy	An alcohol and drug policy is in place and enforced	No
Passenger safety	All passengers are required to sit on a vehicle seat and no passengers are allowed to: • Be transported on trailers • Sit on edges of open vehicles • Stand in or on a vehicle while it is driving	No
Seat belts and restraints	The use of seat belts are enforced whenever: • Public roads are used • The vehicle drives faster than 20km/h	No
Servicing of vehicles	All vehicles are serviced on a regular basis or as necessary	No
Checking vehicles before use	Beyond regular servicing the following simple checks are important to help improve safe motoring. • Tyre pressure • Necessary tools available • Engine oil level and leaks • Coolant • Wiper blades • Windscreen damage • Lights • All dashboard instruments working • Battery functioning correctly • Brake fluid • Steering fluid	No
Notes & Recommendations		
Alcohol & drug policy	No written policy in place but a simple smell & behavior test is done to determine any form of intoxication.	

Travel & Health Advice for Clients

Risk	Explanation	Compliance
	Health & Safety	
Insurance	All clients are advised to sure that they have adequate health insurance and that it covers them for evacuations and for any diving risks.	No
Vaccinations & Malaria	All client are advised, if applicable, of requirements for vaccinations and/or prophylaxis against diseases	No

	such as Hepatitis, Typhoid, Cholera, Yellow Fever, Malaria, etc.	
Travel Health Accessories	All clients are advised to pack the necessary insect repellents, mosquito nets and other applicable gear.	No
Dangers & Annoyances	All clients are informed about the possibility of theft and to make use of the safe in the room and to keep room doors locked when not around.	No
Sunburn & Dehydration	All clients are advised to protect themselves against sunburn and to stay hydrated.	No
Availability of healthcare services & cost	All clients are informed of the availability of healthcare service in the area as well as the general cost to be expected for general check-ups.	No
Emergency Service	All clients are informed prior to their arrival what emergency services and evacuations options are available in case of an emergency.	No
Disease & Environmental Dangers	All clients are informed of what diseases, environmental and animal dangers and hazards are prominent in the area before arrival.	No
Post Exposure Screening	All clients are advised to visit their local travel clinic after returning home if they feel unwell to determine if they have been exposed to any tropical disease.	No
	Costs & General Information	**Recommendations**
General Costs	All clients are advised on what the general cost are for taxis, restaurants and shopping.	No
Tipping	All clients are advised on what the general rules of tipping waiters, hotel staff, taxi drivers etc.	No
Currency	All clients are advised on what currency to use, the exchange rate is the best place to exchange money.	No
ATM's	All clients are advised on the availability of ATM and what service to expect.	No
Cash	All clients are advised when cash is needed for shopping purposes and other services.	No
Credit Cards	All clients are advised on the credit card policy of the facility and the charges to expect for services.	No
Credit Cards	All clients are advised on the credit card policy of the facility and the charges to expect for services.	No
Electricity Supply	All clients are advised on what electricity supply is available and what adaptors to pack.	No
Internet & WIFI	All clients are advised on the availability of internet services and if there are any cost involved to make use of the service if available.	No
	Visas	**Recommendations**
Visa Requirements	All clients are advised if a Visa is required for travel to the destination.	No
Visa length & cost	All clients are advice before departure what Visa type to apply for if applicable and the cost involved to apply for a Visa.	No
	Documents & Customs	**Recommendations**
Drivers License	All clients are advised to apply for an International	No

	Drivers license if they intend to rent a car or motorcycle.	
Health Card	All clients are advised if it is necessary to present a certificate of vaccination when entering the country.	No
Customs	All clients are informed of what is allowed to be exported and what is not. As well as the amount of local and foreign currency allowed in and out of the country.	No
Baggage	All clients are advised on the baggage limitations on domestic and International flights.	No
	Getting Around	**Recommendations**
Boat	All clients are advised if transfer by boat is applicable. Clients are advised what type of water transport to expect and if there is any additional cost involved.	No
Car & Motorcycle	All clients are advised if transfer by road is applicable. Clients are advised what type of transport to expect and if there is any additional cost involved.	No
Air	All clients are advised if transfer by air is applicable. Clients are advised what type of transport to expect and if there is any additional cost involved.	No
Self-drive Options	All clients are advised on any self-drive option such as renting a car or motorcycle to explore the surround area and the costs involved.	No
	Weather	**Recommendations**
General Weather Information	All clients are advised on the general weather conditions throughout the year.	No
Best time to travel	All clients are advised on the best time to travel and which time of the year to avoid travelling to the destination if applicable.	No
	History & Culture	**Recommendations**
General History	All clients are informed of the general history of the destination and how it compares to modern day lifestyle.	No
Language	All clients are advised on what languages are spoken in the area.	No
What to wear	All clients are advised what the appropriate dress code is for the destination. As well as what to clothes to pack for the different seasons.	No
Notes & Recommendations		
Insurance		
Vaccinations & Malaria		
Travel Health Accessories		
Dangers & Annoyances		
Sunburn & Dehydration		

Availability of healthcare services & cost	
Emergency Service	
Disease & Environmental Dangers	
Post Exposure Screening	
General Costs	
Tipping	
Currency	
ATM's	
Cash	
Credit Cards	
Credit Cards	
Electricity Supply	
Internet & WIFI	
Visa Requirements	
Visa length & cost	
Drivers License	
Health Card	
Customs	
Baggage	
Boat	
Car & Motorcycle	
Air	
Self-drive Options	
General Weather Information	
Best time to travel	
General History	
Language	
What to wear	