SCIENTIFIC JOURNAL OF POLISH NAVAL ACADEMY
ZESZYTY NAUKOWE AKADEMII MARYNARKI WOJENNEJ

2018 (LIX) 2 (213)

sciendo

DOI: 10.2478/sjpna-2018-0010

SELECTED DECOMPRESSION PROCEDURES FOR SURVIVORS WHO BECAME SATURATED IN A SUNKEN WRECK

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ABSTRACT

This article is one of the series dedicated to the *DiveSMART Baltic* project conducted to better coordination of international underwater rescue operations in the Baltic Sea. The project *DiveSMART Baltic* has received Flagship status.

The article is the forth in the planned cycle of articles referring tasks realised in the Naval Academy in the framework of *DiveSMART Baltic* project. This article describes selected decompression procedures for victims who became saturated by air at maximum depth to $H = 30\ mH_2O$ in the air pockets of the hull of a sunken wreck. This subject is associated with the work package four *'Medical treatment' of the DiveSMART Baltic project: Identifies methods for different medical treatments in operational areas*.

Key words:
SAR, underwater search and rescue.

Research article

INTRODUCTION

Since the 1970s NOAA[1] has carried out a lot of research in the field of Nitrox[2] Nx saturations. During the long-time use of these systems only a few cases of DCS have been recorded. This system also contains integral treatment tables (1–3).

The $NOAA$'s experience encourages considering using them to rescue survivors. The decompression methods described here constitute a summary of the experience described in the 4th edition of the manual [5].

Tab. 1. Air decompression from the maximum depth of air saturation plateau to 50 fsw [5]

Time [min]	Depth [fsw]	Decompression rate [$fsw \cdot min^{-1}$]
120	$50 \rightarrow 30$	6
44	$30 \rightarrow 28$	22
46	$28 \rightarrow 26$	23
48	$26 \rightarrow 24$	24
50	$24 \rightarrow 22$	25
52	$22 \rightarrow 20$	26
54	$20 \rightarrow 18$	27
56	$18 \rightarrow 16$	28
87	$16 \rightarrow 13$	29
90	$13 \rightarrow 10$	30
62	$10 \rightarrow 8$	31
64	$8 \rightarrow 6$	32
68	$6 \rightarrow 4$	33
68	$4 \rightarrow 2$	34
68	**1**	**68 *min***
The whole decompression time using air 975 min (16: 15). The speed of transfer to the first decompression station is the same as for the transfer between stations.		

According to $NOAA$, air saturations can be made to the plateau depth of 50 fsw (15 mH_2O) and Nx to the plateau depth of 100 fsw (30 mH_2O). The $NOAA$ system has the capability to take into account excursions from the saturation plateau to the maximum depth $of\ H = 250\ fsw$. Within the whole range of depths, Nx in which the oxygen partial pressure is within the range of $p_{O_2} \in [21;\ 50]\ kPa$ can be used for breathing. In the new $NOAA$ systems the Nx decompression is calculated for the lower limit of this pressure for the so called $normobaric\ Nitrox\ norm - Nx$, for which the oxygen partial pressure is $p_{O_2} = 21\ kPa$.

[1] **N**ational **O**ceanic and **A**tmospheric **A**dministration.
[2] Nitrox-oxygen mixtures.

The choice of the decompression profile is based on: the plateau depth of saturation, type of breathing gas, depth of the last excursion from the saturation plateau, etc. So far $NOAA$ has used four decompression systems. In 1976 a decompression system performed after air saturation was developed. Initially it was designed for the maximum plateau depth of 60 fsw (18 mH_2O), but it was modified by limiting this depth to 50 fsw (15 mH_2O) — tab. 1.

In the next system oxygen was used in order to intensify the decompression process — tab. 2. This system was used during the $HYDROLAB$ experiment, when over.

Tab. 2. Air-oxygen decompression from the maximum depth of air saturation plateau to 42 fsw [5]

Depth [*fsw*]	Decompression rate [$fsw \cdot min^{-1}$]	Time [*min*]	Type of breathing gas
$42 \rightarrow 24$	2	9	air
24		180	
$24 \rightarrow 20$	1	4	
20		180	
$20 \rightarrow 16$	1	4	
16		180	
$16 \rightarrow 12$	1	4	
12		75	oxygen
$12 \rightarrow 8$	1	4	air
8		80	oxygen
$8 \rightarrow 4$	1	4	air
4		90	oxygen
$4 \rightarrow$ area	1	4	air
Total decompression time: 418 *min* (*13:38*). There exists a possibility to undergo decompression in the habitat at the bottom, after which the pressure in the habitat has to be increased at the rate of 30 $fsw \cdot min^{-1}$ and then divers can freely surface.			

300 man-decompressions were carried out during which only one case of DCS[3] was recorded. This procedure is interesting in relations to their application in rescue operations as decompression can be carried out in the rescue habitat. After it is completed a second compression can be carried out to the depth of the habitat at the rate of 30 $fsw \cdot min^{-1}$. On completion of the compression free surfacing is possible.

[3] However, it occurred during the flight following the decompression, apart from that three other doubtful cases were treated.

Another two $NOAA$ systems developed for $norm - Nx$ are presented in tab. 3 and tab. 4. The system described in tab. 3, at present, constitutes the standard procedure whereas the system described in tab. 4 constitutes the extended emergency procedure[4]. The latter is used when various premises indicate an increase in *DCS* hazard, as in the case of people being rescued.

Tab. 5 contains the basic information on all the $NOAA$ decompression systems presented. *The* $NOAA$ Saturation tables can be used in the course of rescuing survivors who have got stuck in a wreck of a sunken ship, provided that the oxygen partial pressure has not dropped below $p_{O_2} \geq 21\ kPa$. Exceeding the magnitude of $p_{O_2} > 50\ kPa$ has an effect on the possibility to reduce decompression time[5], but in the system presented preferred are decompression conditions in which there does not occur oxygen toxicity hazard. This causes some problems with regard to intensification of the rescue operation.

Tab. 3. Standard air-oxygen decompression from the saturation plateau after $norm - Nx$ saturation [5]

A	B			C		
Depth range of saturation plateau [fsw]	Decompression to the first decompression station			Further decompression stations		
	Depth [fsw]	Type of breathing gas	Time at stop [$h:min$]	Depth [fsw]	Type of breathing gas	Time at stop [$h:min$]
96–100	80	air	1:30	75	air	2:15
91–95	75		1:30	70		2:25
86–90	70		1:30	65		2:30
81–85	65		1:35	60		2:35
76–80	60		1:40	55		2:40
71–75	55		1:40	50		2:45
66–70	50		1:45	45		2:45
61–65	45		1:45	40		2:00
56–60	40		0:30	40	oxygen	0:30
				35		1:00
51–55	35	oxygen	0:45	30	air	0:30
				30	oxygen	1:00
46–50	30	oxygen	0:45	25	air	2:00
				25	oxygen	1:00
41–45	25	oxygen	1:00	20	air	0:30
				20	oxygen	1:00
36–40	20	oxygen	1:00	15	air	2:00

[4] Conservative.

[5] This, however causes increased riskof oxygen toxiticity.

A	B			C		
31–35	15		0:30	15	oxygen	1:00
26–30	10		0:30	10	air	0:30
				10	oxygen	1:00
				5	air	0:30
				5	oxygen	0:30
22–25	5	Oxygen	0:30	30		0:30
0–21	without limits			surface		

Choose depth of saturation plateau in column **A**, move parallel to column **B** in order to determine the first decompression station and move to column **C** in order to decide about further decompression.
Ascent rate is not precisely determined and should be within $v \in [1; 30] fsw \cdot min^{-1}$.
Time to reach the station is counted in the time at stop at the station towards which the diver moves.
Descent rate after 30 min at stop at station 30 fsw must not exceed $v < 10\ fsw \cdot min^{-1}$.

Tab. 4. Extended air-oxygen decompression from the saturation plateau $norm - Nx$ [5]

A	B			C		
Range of depths for saturation plateau $[fsw]$	Decompression to the first decompression station			Further decompression stations		
	Depth $[fsw]$	Type of breathing gas	Time at stop $[h:min]$	Depth $[fsw]$	Type of breathing gas	Time at stop $[h:min]$
96–100	80	air	3:00	75	air	4:00
91–95	75		3:00	70		4:00
86–90	70		3:00	65		4:30
81–85	65		3:00	60		4:30
76–80	60		3:00	55		5:00
71–75	55		3:30	50		5:00
66–70	50		3:30	45		5:00
61–65	45		3:30	40		5:00
56–60	40		4:00	35		0:30
				35	oxygen	1:00
51–55	35	oxygen	1:00	35	air	0:30
				35	oxygen	1:00
				30	air	2:00
46–50	30	air	2:00	30	oxygen	1:00
				25	air	0:30
				25	oxygen	1:00
41–45	25	air	0:30	25	air	0:30
				25	oxygen	1:00
				20	air	3:00
36–40	20	air	1:30	20	oxygen	1:00
				15	air	0:30
				15	oxygen	1:00
31–35	15	air	1:00	15	air	0:30
				15	oxygen	1:00

A	B			C		
				10	air	4:00
26–30	10	air	2:00	10	oxygen	1:00
				5	air	0:30
				5	oxygen	1:00
				5	air	0:30
				5	oxygen	1:00
22–25	5	oxygen	0:30	30		0:30
0–21	without limits			surface		

Choose depth of saturation plateau in column **A**, move parallel to column **B** in order to determine the first decompression station and move to column **C** in order to decide about further decompression.
Ascent rate is not precisely determined and should be within $v \in [1; 30] fsw \cdot min^{-1}$
Time to reach the station is counted in the time at stop at the station towards which the diver moves.
Descent rate after 30 min at stop at station 30 fsw must not exceed $v < 10\ fsw \cdot min^{-1}$.

Tab. 5. Aggregate information on NOAA decompression systems following Nx saturation [5]

Maximum depth of saturation plateau [fsw]	Decompression time from saturation plateau [h]					Time of breathing with oxygen	Reference to table
	Saturation plateau [fsw]						
	maximum	100	80	60	40	[h]	
50	16,3				15,3	—	**1**
42	13,6				13,6	4,1	**2**
100	34,9	36,0	25,3	14,0	7,0	7,5	**3**
100	64,5	64,5	47,5	28,5	14,0	11,5	**4**

Range of depths of saturation plateau [fsw]	Use of oxygen during decompression	Procedure detailed in table	Remarks
0–26	no	zero decompression*	If the nitrogen partial pressure of does not exceed 47 fsw, e.g. for air saturation at plateau depth of 46 fsw
26–50	no	**1**	Procedure developed for decompression following air saturation to maximum plateau depth of 50 fsw
42	yes	**2**	Procedure developed for air saturation to plateau depth of 42 fsw or shallower
22–100	yes	**3**	Standard decompression following $norm - Nx\ saturation$
22–100	yes	**4**	Conservative decompression procedure following $norm - Nx$ saturation recommended when increased *DCS* hazard is expected

* ascent not faster than gas bubbles freely surfacing is required so that pressure-caused lung injury would not occur

It seems that research should be carried out in order to develop decompression methods to be used following Nx saturation with regard to a wider range of oxygen partial pressure values, over $p_{O_2} > 50\ kPa$. However, this can lead to an increased risk of central nervous system toxicity *CNS*[6].

EXCURSIONS WITH DIRECT DECOMPRESSION

Zero or direct decompression is the term used to describe the procedure for decreasing pressure defined as the pressure for which ascent rate v does not produce a risk of pressure-caused lung injury as barotrauma. In practice it is determined as ascending not faster than free movement of gas phase in water depths towards the surface. Sometimes $zero\ decompression$ takes into account safety stops which are constant for a given procedure. The term $zero\ decompression$ is used in order to eliminate a slang expression of $no\text{-}decompression\ ascent$ suggesting that the ascent is not accompanied by decompression processes, which is not true. $Zero\ decompression$ can vary with different systems as it is determined for a certain safety level of the further course of $normobaric\ decompression$, which occurs after the surface has been reached. For saturated systems the zero decompression rate is most often determined at the level $of\ v = 1\ fsw \cdot min^{-1}$.

The $NOAA$ decompression system takes into account the possibility of making excursions from an Nx saturation plateau both with $zero\ decompression$ and excursions which require decompression. The breathing gas used during excursions is air. The decompression systems have been calculated also for time periods without taking into account limits of exposition to oxygen, which can be interesting in the case of rescuing survivors.

Tab. 6 presents allowable time periods for excursions from a saturation plateau using air or $norm - Nx$ as the breathing gas, taking into account oxygen expositions presented in tab. 8. Only the shaded area profile types in tab. 6 represents expositions for which this limits of exposition to oxygen were not taken into account. Tab. 7 gives the maximum exposition times without taking into account oxygen expositions presented in tab. 8.

The correct selection of time allowed for an excursion with $zero\ decompression$ from the Nx saturation plateau for intermediate values, out of the values listed in the tables, must be rounded upwards to the next depth of the Nx saturation plateau represented in the table and the next greater depth H represented in the table.

[6] **C**entral **N**ervous **S**yndrome.

Tab. 6. Allowable air excursions from norm — Nx saturation plateau for zero decompression [5]

Excursion depth [*fsw*]	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215
Oxygen partial pressure [*kPa*]	72	75	78	81	84	88	91	94	97	101	103	107	110	113	116	119	122	126	129	132	136	138	142	145	148	151	154	157
Saturation plateau depth [*fsw*]	Allowable excursion time from norm — *Nx* saturation plateau with zero decompression [*min*]																											
35	350	267	156	113	91	78	68	60	55	50	45	40	36	32	28	24	22	18	15	13	12	11	10	9	8	8	7	7
40	*	*	283	229	143	108	89	77	68	61	54	46	41	37	34	31	28	25	22	20	16	14	13	11	10	9	9	8
45	*	*	*	301	240	202	147	112	92	80	70	59	50	44	39	35	32	30	28	25	23	21	17	15	13	12	11	10
50	*	*	*	*	323	253	210	181	137	108	91	69	56	48	42	38	34	31	29	27	25	23	22	21	18	16	14	12
55	*	*	*	*	*	350	267	219	187	164	140	86	64	53	45	40	36	33	30	28	26	24	22	21	20	19	18	16
60	*	*	*	*	*	*	314	245	203	174	153	137	86	63	52	45	40	36	32	30	27	25	24	22	21	20	19	18
65	*	*	*	*	*	*	*330*	284	224	187	161	142	127	85	63	52	45	39	35	32	29	27	25	23	22	21	19	18
70	*	*	*	*	*	*	*330*	315	236	191	162	145	128	111	85	63	51	44	39	35	32	29	27	25	23	22	20	19
75	*	*	*	*	*	*	*330*	*330*	279	213	174	148	129	114	103	84	62	51	44	39	35	31	29	26	25	23	21	20
80		*	*	*	*	*	*330*	*330*	*300*	*270*	*270*	*240*	228	191	165	145	95	66	53	45	40	35	32	29	27	25	23	22
85			*	*	*	*	*330*	*330*	*300*	*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	122	70	55	47	41	36	32	29	27	25	23
90				*	*	*	*330*	*330*	*300*	*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	*180*	*180*	95	66	54	46	40	36	32	29	27
95					*	*	*330*	*330*	*300*	*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	*180*	*180*	*165*	*150*	97	68	55	47	41	37	33
100						*	*330*	*330*	*300*	*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	*180*	*180*	*165*	*150*	*150*	*135*	113	80	62	52	*45*
105							*330*	*330*	*300*	*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	*180*	*180*	*165*	*150*	*150*	*135*	*135*	*120*	*83*	*83*	*45*
110								*330*	*300*	*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	*180*	*180*	*165*	*150*	*150*	*135*	*135*	*120*	*83*	*83*	*45*
115									*300*	*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	*180*	*180*	*165*	*150*	*150*	*135*	*135*	*120*	*83*	*83*	*45*
120										*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	*180*	*180*	*165*	*150*	*150*	*135*	*135*	*120*	*83*	*83*	*45*
125										*270*	*270*	*240*	*240*	*225*	*210*	*210*	*195*	*180*	*180*	*165*	*150*	*150*	*135*	*135*	*120*	*83*	*83*	*45*

* asterix is used to mark exceeded time limit 360 *min*
shaded areas represent zero decompression for excursions in which oxygen exposition limits presented in tab. 15 were exceeded

Tab. 7. Excursions with zero decompression from norm − Nx saturation plateau without taking into account oxygen exposition limits contained in tab. 8 [5]

Excursion depth [*fsw*]	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250
Oxygen partial pressure [*kPa*]	72	75	78	81	84	88	91	94	97	101	103	107	110	113	116	119	122	126	129	132	136	138	142	145	148	151	154	157	161	164	167	171	173	176	180
Saturation plateau depth [*fsw*]	Allowable time of excursion from *norm* − Nx saturation plateau with zero decompression [*min*]																																		
30	350	267	156	113	91	78	68	60	55	50	45	40	36	32	28	24	22	18	15	13	12	11	10	9	8	8	7	7	6	6	5	5	5	5	
35	*	*	283	229	143	108	89	77	68	61	54	46	41	37	34	31	28	25	22	20	16	14	13	11	10	9	9	8	7	7	6	6	6	5	5
40	*	*	*	301	240	202	147	112	92	80	70	59	50	44	39	35	32	30	28	25	23	21	17	15	13	12	11	10	9	8	8	7	7	6	6
45	*	*	*	*	323	253	210	181	137	108	91	69	56	48	42	38	34	31	29	27	25	23	22	21	18	16	14	12	11	10	9	9	8	8	7
50	*	*	*	*	*	350	267	219	187	164	140	86	64	53	45	40	36	33	30	28	26	24	22	21	20	19	18	16	14	13	12	11	10	9	8
55	*	*	*	*	*	*	314	245	203	174	153	137	86	63	52	45	40	36	32	30	27	25	24	22	21	20	19	18	17	15	13	12	11	10	9
60	*	*	*	*	*	*	*	284	224	187	161	142	127	85	63	52	45	39	35	32	29	27	25	23	22	21	19	18	17	17	15	13	14	11	10
65	*	*	*	*	*	*	*	315	236	191	162	145	128	111	85	63	51	44	39	35	32	29	27	25	23	22	20	19	18	17	16	16	14	12	11
70	*	*	*	*	*	*	*	*	279	213	174	148	129	114	103	84	62	51	44	39	35	31	29	26	25	23	21	20	19	18	17	16	15	14	13
75	*	*	*	*	*	*	*	*	*	*	*	288	228	191	165	145	95	66	53	45	40	35	32	29	27	25	23	22	20	19	18	17	16	16	15
80		*	*	*	*	*	*	*	*	*	*	*	*	*	317	225	215	122	70	55	47	41	36	32	29	27	25	23	22	20	19	18	17	16	15
85			*	*	*	*	*	*	*	*	*	*	*	*	*	*	328	265	225	95	66	54	46	40	36	32	29	27	25	23	22	22	19	18	17
90				*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	339	275	168	97	68	55	47	41	37	33	30	28	26	24	23	21	20
95					*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	306	227	143	113	80	62	52	46	40	37	33	31	28	26	25
100						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	341	281	193	135	109	93	72	59	50	44	40	36	33	31
105							*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	354	308	262	174	129	107	77	62	53	46	41	38	35
110								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	334	294	257	176	132	83	65	55	48	43	39
115									*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	347	303	270	243	163	91	68	57	49	44
120										*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	329	291	261	237	101	72	59	51

* asterics is used to mark exceeded time limit 360 *min*

During excursions from a plateau air should be used for breathing and the maximum allowable excursion depth is 215 fsw ($\cong$ 66 mH_2O). An immediate excursion below the saturation plateau is possible following the excursion to the depth smaller than that of the saturation plateau. The return rate to the saturation plateau should not be higher than $v \leq 30\ fsw \cdot min^{-1}$. Short excursions to the depths greater than that of the saturation plateau have only little effect on the increase in *DCS* risks during excursions that follow them to the depths smaller than that of the saturation plateau provided they occur after minimum 4 *hrs* of rest — tab. 9. Long excursions below the saturation plateau have significant effect on the possibility of undertaking further safe excursions. A successive excursion following a six-hour-long excursion can be made to the depths H greater than $H > 30\ fsw$ below the saturation plateau only after 36 *hrs* of rest. There exists a possibility of conducting an earlier additional emergency excursion but from the rescue point of view this issue has little significance and will not be discussed here.

Tab. 8. Allowable combinations of oxygen partial pressure and time of exposition to oxygen accepted by NOAA [5]

Standard expositions				
Oxygen partial pressure [kPa]	Allowable exposition time		Maximum exposition time during 24 hrs	
	[min]	[$hour$]	[min]	[$hour$]
160	45	0.75	150	2.5
150	120	2.0	180	3.0
140	150	2.5	180	3.0
130	180	3.0	210	3.5
120	210	3,5	240	4.0
110	240	4.0	270	4.5
100	300	5.0	300	5.0
90	360	6,0	360	6.0
80	450	7.5	450	7.5
70	570	9,5	570	9.5
60	720	12.0	720	12.0
Exceptional expositions				
200	*30*	*0.50*		
190	*45*	*0.75*		
180	*60*	*1.00*		
170	*75*	*1.25*		
160	*120*	*2.0*		
150	*150*	*2.5*		
140	*180*	*3.0*		
130	*240*	*4.0*		
– if one of the dives led to using or exceeding allowable exposition time, the diver has to rest at surface for at least 2 *hrs* prior to further expositions – if one or many of the dives during 24 *hrs* led to using or exceeding the maximum exposition time set for the 24 *hrs*, the diver has to rest at surface for minimum 12 *hrs* prior further expositions [6]				

Oxygen partial pressure p_{O_2} at the saturation plateau does not affect the possibility of conducting excursions as long as it is within the allowable limits. It should be noted, however, that with regard to rescue procedures there can often occur an unplanned situation when the oxygen partial pressure p_{O_2} will be below the normoxic limit. Use of depleted air as a breathing gas must be taken into account if the excursion procedures are to be used as rescue procedures by both victims and rescuers.

DECOMPRESSION EXCURSIONS

The $NOAA$ decompression tables also allow for conducting short excursions during the return to the saturation plateau. To this end the $US\ Navy$ air decompression tables are used, following their appropriate conversion [7]. The diving depth is regarded as the excursion depth below the saturation plateau, and the time of stay at the bottom as the time of excursion. The particular decompression stations must be appropriately converted in relation to the depth of the saturation plateau.

The final decompression from the saturation plateau cannot be conducted immediately after the return from the excursion to the depth below the saturation plateau. The required times of rest following an excursion are shown in tab. 9. When it is necessary to initiate immediate decompression the saturation plateau can be lifted to the excursion depth and the decompression can be begun from the new saturation plateau.

Tab. 9. Required rest time which must pass following an excursion from a saturation plateau till the moment of beginning decompression from the saturation plateau [5]

Depth of excursion below saturation plateau [fsw]	Excursion time [$hour$]	Time that must pass prior to decompression from saturation plateau [$hour$]
all allowable depths	<1	4
<50	1–2	4
<50	2–4	12
<50	>4	24
50–100	1–2	16
50–100	>2	36
>100	1–2	30
>100	>2	48

SATURATION TREATMENT TABLES

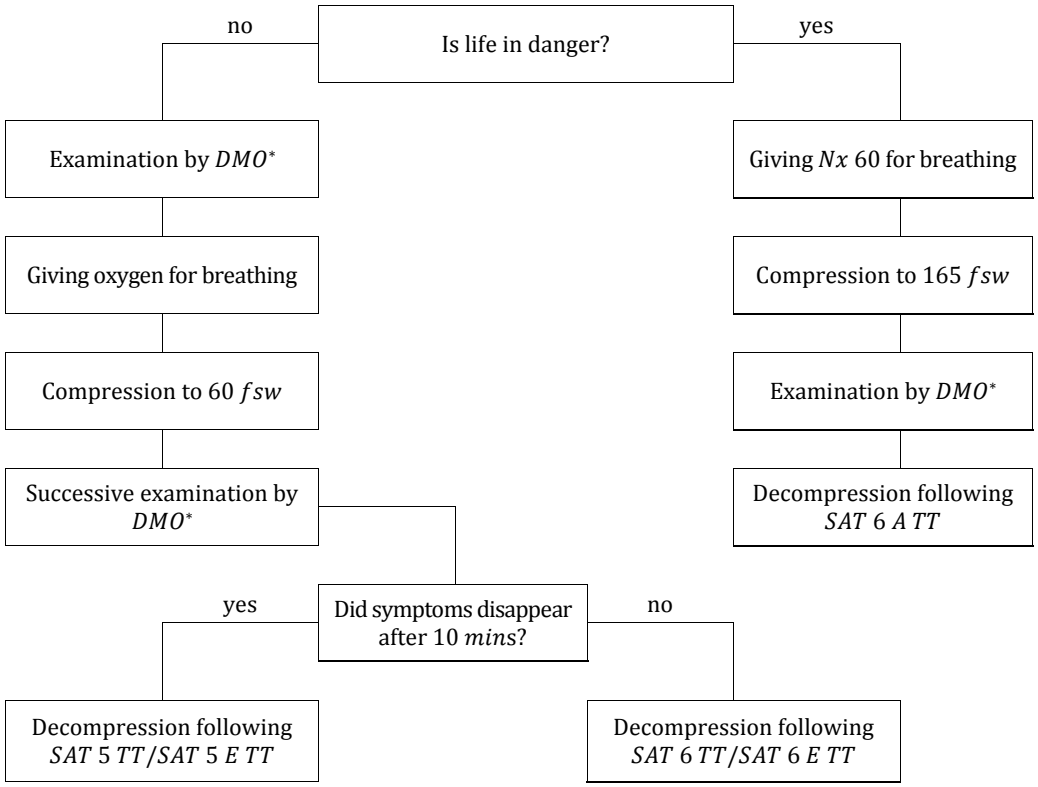
No matter if the *DCS* symptoms have occured or are expected on completion or in the course of the excursion, or after decompression from the saturation plateau, the diver should be examined by a *DMO* and they should undergo treatment decompression/ recompression using oxygen.

Even if the *DCS* symptoms are only highly likely, treatment should be immediately undertaken. The choice of the appropriate *TT* is facilitated by the information contained in tab. 10.

Treatment can vary depending on the operation stage at which the *DCS* symptoms occurred. If they occurred on completion of the saturation or towards the end of decompression from the saturation plateau, the divers should be given treatment decompression. If the *DCS* symptoms occured as a result of the completed excursion from the saturation plateau, the diver(s) taking part in the excursion must be separated and given treatment decompression. The set of saturation decompression/recompression tables is included in tab. 11–13. Saturation recompression tables are collected in *Appendix VI NOAA* diving manual [5]. In Chapter 17 Sec.6.2 Emergency Recompression in the habitat provide some valuable recommendations for conducting treatment of decompression sickness during *Nx* saturations [5].

Tab. 10. Basic parameters of NOAA saturation decompression tables for treatment decompression and the procedure for their use [5]

№ *TT**	Maximum depth [*fsw*]	Comment
SAT 5	60	Emergency evacuation form saturation plateau
SAT 5 *E*	60	Emergency version of *SAT* 5 *TT* used when maximum reduction in treatment time is required, e.g .because of weather conditions or equipment failure
SAT 6	60	For treatment of *DCS* on completion of excursion from saturation plateau
SAT 6 *E*	60	Emergency version of *SAT* 6 *TT* used when maximum reduction in treatment time is required, e.g. because of weather conditions or equipment failure
SAT 6 *A*	165	For treatment of serious *AGE*** symptoms
All treatment tables require use of oxygen; ***T**reatment **T**ables; ****A**rterial **G**as **E**mbolism		



*Diving Medical Officer

Tab. 11. Saturation tables NOAA SAT 5 TT and NOAA SAT 5E TT for treatment decompression [5]

Depth [fsw]	SAT 5			SAT 5 E		
	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas
60	20	0:20	oxygen	20	0:20	oxygen
60	5	0:25	air	5	0:25	air
60	20	0:45	oxygen	20	0:45	oxygen
60 → 45	15	1:00	oxygen	15	1:00	oxygen
45	15	1:15	oxygen	15	1:15	oxygen
45 → 30	*5**	*1:20**	*air**	*5**	*1:20**	*air**
30	20	1:40	oxygen	20	1:40	oxygen
30	5	1:45	air	5	1:45	air
30 → 25	5	1:50	oxygen	5	1:50	oxygen
25	5	1:55	oxygen	5	1:55	oxygen
25 →	5	2:00	air	5	2:00	oxygen

Depth [fsw]	*SAT* 5			*SAT* 5 *E*		
	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas
20						
20	85	3:25	air	55	2:55	oxygen
20	60	4:25	oxygen			
20 → 15	5	4:30	air	5	3:00	air
15	25	4:55	air	115	4:55	air
15	60	5:55	tlen	60	5:55	oxygen
15	30	6:25	air			
15	60	7:25	oxygen			
15 → 10	5	7:30	air	5	6:00	air
10	235	11:25	air	25	6:25	air
10	60	12:25	oxygen	60	7:25	oxygen
10 → 5	5	12:30	air	5	7:30	air
5	25	12:55	air	25	7:55	air
5	60	13:55	oxygen	30	8:25	oxygen
5	30	14:25	air			
5	60	15:25	oxygen			
5 → 30	1	15:26	oxygen	1	8:26	oxygen
30	30	15:56	oxygen	30	5:56	oxygen
30 → 15	*5**	*16:01**	*oxygen**	15		oxygen
15	25	16:26	oxygen	15		oxygen
15 → surface	15	16:41	oxygen	15	9:41	oxygen
descent rate 25 $fsw \cdot min^{-1}$; ascent rate 1 $fsw \cdot min^{-1}$; *ascent rate 3 $fsw \cdot min^{-1}$						

Tab. 12. Saturation tables NOAA SAT 6 TT and NOAA SAT 6E TT for treatment decompression [5]

Depth [fsw]	*SAT* 6			*SAT* 6 *E*		
	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas
60	20	0:20	oxygen	20	0:20	oxygen
60	5	0:25	air	5	0:25	air
60	20	0:45	oxygen	20	0:45	oxygen
60	5	0:50	air	5	0:50	air
60	20	1:10	oxygen	20	1:10	oxygen
60	5	1:15	air	5	1:15	air
60 → 45	15	1:30	oxygen	15	1:30	oxygen
45	15	1:45	oxygen	15	1:45	oxygen
45 → 30	15	2:00	air	15	2:00	air
30	60	3:00	oxygen	60	3:00	oxygen
30	15	3:15	air	15	3:15	air
30	60	4:15	oxygen	60	4:15	oxygen
30 → 25	5	4:20	oxygen	5	4:20	oxygen

Depth [fsw]	*SAT 6*			*SAT 6 E*		
	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas
25	5	4:25	air	5	4:25	air
25 → 20	5	4:30	oxygen	5	4:30	oxygen
20	85	5:55	air	55	5:25	oxygen
20	60	6:55	oxygen			
20 → 15	5	7:00	air	5	5:30	air
15	25	7:25	air	115	7:25	air
15	60	8:25	oxygen	60	8:25	oxygen
15	30	8:55	air			
15	60	9:55	oxygen			
15 → 10	5	10:00	air	5	8:30	air
10	235	13:55	air	25	8:55	air
10	60	14:55	oxygen	60	9:55	oxygen
10 → 5	5	15:00	air	5	10:00	air
5	25	15:25	air	25	10:25	air
5	60	16:25	oxygen	30	10:55	oxygen
5	30	16:55	air			
5	60	17:55	oxygen			
5 → 30	1	17:56	oxygen	1	10:56	oxygen
30	30	18:26	oxygen	30	11:26	oxygen
30 → 15	15	18:41	oxygen	15	11:41	oxygen
15	15	18:56	oxygen	15	11:56	oxygen
15 → surface	15	19:11	oxygen	15	12:11	oxygen
descent rate 25 $fsw \cdot min^{-1}$; ascent rate 1 $fsw \cdot min^{-1}$						

Tab. 13. Saturation table NOAA SAT 6A TT for treatment decompression [5]

Depth [fsw]	SAT 6 A			
	Time of stop/transfer [min]	Operation time [$hour:min$]	Type of breathing gas	Remarks
60	20	0:20	oxygen	
60 → 165	*5*	*0:25*	*air*	*optional*
165	*30*	*0:55*	*air*	
165 → 112	*53*	*1:48*	*air*	
112	*4*	*1:52*	*air*	
112 → 60	*52*	*2:44*	*air*	
60	20	3:04	oxygen	
60	5	3:09	air	
60	20	3:29	oxygen	
60	5	3:34	air	
60	20	3:54	oxygen	
60	5	3:59	air	
60 → 45	15	4:14	oxygen	
45	15	4:29	oxygen	
45 → 30	15	4:44	air	

Depth [*fsw*]	SAT 6 A			
	Time of stop/transfer [*min*]	Operation time [*hour:min*]	Type of breathing gas	Remarks
30	60	5:44	oxygen	
30	15	5:59	air	
30	60	6:59	oxygen	
$30 \rightarrow 25$	5	7:04	oxygen	
25	5	7:09	oxygen	
$25 \rightarrow 20$	5	7:14	air	
20	85	8:39	air	
20	60	8:39	oxygen	
$20 \rightarrow 15$	5	8:44	air	
15	25	10:09	air	
15	60	10:09	oxygen	
15	30	11:39	air	
15	60	12:39	oxygen	
$15 \rightarrow 10$	5	12:44	air	
10	235	16:39	air	
10	60	17:39	oxygen	
$10 \rightarrow 5$	5	17:44	air	
5	25	18:09	air	
5	60	19:09	oxygen	
5	30	19:39	air	
5	60	20:39	oxygen	
$5 \rightarrow 30$	1	20:40	oxygen	
30	30	21:10	oxygen	
$30 \rightarrow 15$	15	21:25	oxygen	
15	15	21:40	oxygen	
$15 \rightarrow$ surface	15	21:55	oxygen	
descent rate 25 $fsw \cdot min^{-1}$; ascent rate 1 $fsw \cdot min^{-1}$				

CONCLUSIONS

The *NOAA* saturation system can be used for decompression of victims who have been air saturated in a sunken wreck. At the maximum depth 15 mH_2O the system can be applied without any objection, but between depths from 15 mH_2O to 30 mH_2O after assessing the risk of pulmonary toxicity[7] [3, 4]. It is worth reflecting on the recalculation the *NOAA* system for the decompression of victims at lower partial oxygen pressure, re-ducing the impact of pulmonary oxygen toxicity.

[7] In the *NOAA* saturation system, air saturation is only allowed to the maximum depth of 50 fsw (15 mH_2O), but the deeper plateau is only reached by means of Nx with a lower concentration of oxygen than in air, up to maximum depth of 100 fsw (30 mH_2O).

Some *NOAA* procedures are very promising with regard to their use for recompression of survivors who experienced air saturation in the wreck of a sunken ship. In this case it is tab. 13 that is especially important, as decompression can be carried out in the rescue habitat and the victim can be compressed again at the rate $v = 30\ fsw \cdot min^{-1}$, and then it is possible for him/her to freely surface. Similarly the treatment decompression tables can be used to treat *DCS* in castaways.

The *NOAA* saturation system is also the preferred system for divers who will penetrate a wreck for in search of casualties. In this case, it would be useful to use the excursion tab. 6 and 7. Choosing the same system for victims and divers will give the opportunity to transfer the victims also to the habitat from which the divers operate.

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WYBRANE PROCEDURY DEKOMPRESYJNE DLA ROZBITKÓW, KTÓRZY ZOSTALI PODDANI SATURACJI WE WRAKU ZATOPIONEJ JEDNOSTKI PŁYWAJĄCEJ

STRESZCZENIE

Artykuł należy do serii dotyczącej projektu *DiveSMART*, który jest związany z zapewnieniem lepszej koordynacji międzynarodowej akcji ratownictwa podwodnego w rejonie Morza Bałtyckiego. Projekt ten otrzymał status „projektu flagowego".

Artykuł jest czwartym z cyklu artykułów opisujących zadania realizowane przez Akademię Marynarki Wojennej w ramach projektu $DiveSMART$. Scharakteryzowane są w nim wybrane procedury dekompresji poszkodowanych, którzy ulegli saturacji powietrznej na maksymalnej głębokości do $H = 30\ mH_2O$ w powietrznych pułapkach wewnątrz zatopionego wraku. Tematyka dotyczy realizacji zadania czwartego pt. '*Medical treatment' of the DiveSMART project: Identifies methods for different medical treatments in operational areas*.

Słowa kluczowe:
SAR, poszukiwania i ratownictwo podwodne.

Article history
Received: 05.02.2018
Reviewed: 16.04.2018
Revised: 19.04.2018
Accepted: 20.04.2018