POLISH HYPERBARIC RESEARCH 1(62)2018
Journal of Polish Hyperbaric Medicine and Technology Society
Faculty of Mechanical and Electrical Engineering of the Polish Naval Academy

MICROBIAL CONTAMINATION OF A DIVING SUIT

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ABSTRACT

Pathogenic micro-organisms can easily transfer from the surface of a diver's skin onto the surfaces of a protective suit. A long-term stay in a hyperbaric chamber during a saturation dive increases the risk of infection if in the chamber there is even a single carrier of disease-causing pathogens.
The conducted research has confirmed that the diving equipment located in Diving Centres is a place of many different bacteria and fungi, including pathogenic ones. The vast majority of microbes found on the surfaces of wetsuits, etc. are commensals (with some being opportunistic organisms). This fact allows us to realise that the surfaces of diving equipment are an excellent "transmission route" for various dermatoses and other diseases. In order to reduce the risk of infection the diving equipment used by various people should be subject to the process of decontamination. The authors recommend decontamination with the use of gaseous hydrogen peroxide which does not cause damage to equipment.
Keywords: diving, diving suit, contamination.

ARTICLE INFO

PolHypRes 201 Vol. 62 Issue 1 pp. 61 - 74
ISSN: 1734-7009 **eISSN:** 2084-0535
DOI: 10.2478/phr-2018-0005
Pages: 14, figures: 6, tables: 2
page www of the periodical: www.phr.net.pl

Publisher
Polish Hyperbaric Medicine and Technology Society

Rewiev article

Submission date: 05.01.2018
Acceptance for print: 15.03.2018

INTRODUCTION

In 2003, Wang et al. [1] reported a case of infection with Methicillin-resistant *Staphylococcus aureus* (MRSA) in 6 divers exposed to a 45-day exposure in saturated conditions. The source of the infection was one of the divers. The most probable transmission route of the infection was a direct contact between the infected diver and other participants of the exposure. The bacteria of the *Staphylococcus* genus colonise the skin of every human being, constituting its natural physiological bacterial flora, however it should be remembered that in altered conditions the same species may cause infections. *Staphylococcus aureus* mainly colonises the nasal vestibule and can be found in approximately 40% of people. Its presence in humans is referred to as carrier state.

Staphylococcus aureus may be the cause of local infections, virtually affecting all tissues and organs, as well as generalised, often life-threatening ones. The most common are purulent inflammations of the skin and soft tissues: furuncles, sties, impetigo, abscesses, purulent fungi and bone marrow inflammation, septic arthritis, endocarditis and pneumonia. The incubation period (time from the contact with the pathogen to the first symptoms) is between 4 and 10 days.

In the work of Hind et al. [2], the effect of an increasing drug resistance of disease-causing pathogens was noted in relation to *Staphylococcus aureus*, *Escherischia coli* and *salmonenella typhimirium* in the conditions of an increased pressure during saturation diving (heliox, 36 and 71 bar).

Pathogenic micro-organisms can very easily transfer from the surface of a fabric onto the body of a worker using a protective suit.

In addition, there is a risk of transferring pathogenic micro-organisms between people using the same work clothes, particularly in the case of expensive, specialist suits. Micro-organisms that can potentially spread through clothing include intestinal bacteria such as: *Salmonella, Shigella, Campylobacter, E. coli* (including *E. coli O157*), *C.difficile* that cause infections of upper respiratory tract and digestive tract (noraviruses, rotaviruses, adeno and astroviruses).

The risk of infection also includes influenza viruses, herpesviruses, and pathogens transmitted through the skin, such as *S. aureus* (including MRSA), yeast-like fungi (*Candida albicans*), strains of fungi that cause *Tinea pedis* (foot tinea) and *Tinea corporis* (mycosis of smooth skin) [3].

It is estimated that a person may emit approximately one million dead skin cells per day, which may contain fungi and bacteria, including *S. aureus* [4].

The survival of micro-organisms on different surfaces depends on the type of fabric, humidity and temperature, as well as the initial pathogen concentration. Neeley and Maley studied the survival of 22 species of Gram-positive bacteria on such fabrics as: 100% cotton, 60% cotton + 40% polyester, 100% polyester.

All micro-organisms survived on selected materials for at least 1 day, and some of them for as many as 90 days. In general, the survival rate of bacteria, viruses and fungi on smooth hydrophobic surfaces is at least 2-4 times higher as compared with such fabrics as pure cotton (smooth, terry) or cotton / polyester (5,6,7).

Pathogenic micro-organisms can very easily spread from the fabric surface onto the body of a worker using protective clothing. In the work of Sattar et al., it was demonstrated that one of the most important factors determining the rate of transfer of pathogens from the surface of the fabric onto the employee's hand is the fabric's humidity. Drying of the surface can reduce micro-organism transfer by up to 10 times in relation to the transfer from a wet surface onto moist skin [8].

RESEARCH OBJECTIVE

- The research was aimed at determining the degree of microbiological contamination of diving equipment used during planned training.
- The degree of microbiological contamination of the equipment used has no impact on the course of training but may be the cause of numerous dermatoses found in the environment of divers and individuals who have used the services of centres offering such trainings, or diving equipment rental facilities.
- The research was to determine the microbiological quality of diving equipment and demonstrate why it should be subjected to a decontamination process.

RESEARCH COURSE

- Collection of imprints from flat internal and external surfaces of diving suits and wetsuits onto media used for determining the total count of microorganisms as well as those used to indicate the presence of yeasts and fungi.
- Collection of swabs from suits, wetsuits, mouthpieces, masks, life jackets, etc.
- Preparation of collected culture swabs on TSA medium (to demonstrate total count of microorganisms), Chapman's medium (for the presence of Staphylococcus aureus and other Staphylococcus bacteria) and SA medium (for the presence of yeasts, dermatophytes and other fungi).
- Evaluation of cultures.

The level of microbiological contamination of surfaces of diving suits was tested using Orion's imprint tests. Hygicult tests are designed to enable fast monitoring of microbiological hygiene and/or preliminary identification of micro-organisms (total number of bacteria, yeasts, molds and enteric bacilli) on various types of surfaces. The test can be carried out on site or the slides can be used as convenient transport media for cultured samples.

The Hygicult TPC slide is coated on both sides with Total Plate Count agar, which facilitates rapid growth of the most common micro-organisms. The test is designed to detect an elevated total microbial count. The Hygicult Y&F slide is coated on both sides with Malt agar, which facilitates rapid growth of yeast and mold. The growth of bacteria is inhibited. The test is designed to detect an increased count of fungi on the tested surface.

With the use of Hygicult tests we are able to obtain preliminary information regarding not only the

state of microbiological purity, but also that related to the type of micro-organism that causes contamination (depending on the Hygicult test). The collected samples were incubated for 24 hours in an incubator at 35-37^{0}C. Using the attached model, the degree of contamination was determined in cfu/cm^2.

RESULTS

Tables 1 and 2 present the microbiological contamination of selected fragments of suits and diving equipment.

Tab. 1

Sample collection from diving equipment surfaces on October 6, 2017 (after dives).

No.	place of swab collection	Research results • + small growth 1 – 20 cfu; • ++ large growth 20 – 100 cfu; • +++ very large growth above 100 cfu;				
		Imprint general microbial count	TSA medium general microbial count	SA medium presence of yeasts, dermatophytes and other fungi	Chapman medium	
					presence of *Staphylococcus sp*.	presence of *Staphyolococcus aureus*
1	Diving suit no. 1– inside, armpits	+++	+++	++	+	-
2	Diving suit no. 1 – inside, neck area	++	++	++	++	+
3	No swabs collected					
4	Diving suit no. 2 – inside, crotch area	++	++	++	+	+
5	Diving suit no. 2 – outside	+++	+++	+++	++	+
6	Diving suit no. 3 – inside, hands area	+++	+++	+++	++	++
7	Diving suit no. 3 – inside, armpit	+++	+++	+++	++	++
8	Wetsuit no. 1 – inside, neck area	++	++	++	++	+
9	Wetsuit no. 1 – inside, head	++	++	+	+	+
10	Wetsuit no. 1 – inside, torso	+++	++	++	++	+

Tab. 1 cont,

Sample collection from diving equipment surfaces on October 6, 2017 (after dives).

Research results
- \+ small growth 1 – 20 cfu;
- ++ large growth 20 – 100 cfu;
- +++ very large growth above 100 cfu;

No.	place of swab collection	Imprint general microbial count	TSA medium general microbial count	SA medium presence of yeasts, dermatophytes and other fungi	Chapman medium	
					presence of *Staphylococcus sp*.	presence of *Staphyolococcus aureus*
11	Wetsuit no. 2 – inside, sleeves	++	++	++	++	+
12	Wetsuit no. 2 – inside, legs	+++	+++	+++	+++	-
13	Wetsuit no. 2 – inside, crotch area	+++	+++	+++	+++	+++
14	Wetsuit no. 3 – inside, armpit	+++	++	+++	+	+
15	Wetsuit no. 3 – inside, legs	++	++	+++	+	+
16	Wetsuit no. 3 – outside, zip area	+++	++	++	+++	++
17	Wetsuit no. 4 – inside, head	++	++	++	++	+
18	Wetsuit no. 4 – inside, torso	+++	+++	+++	+++	+
19	Life-jacket – neck area	++	++	++	+++	++
20	Life-jacket – zip area	++	++	++	+++	-

Tab. 2

Sample collection from diving equipment surfaces on October 17, 2017 (before diving).

Research results
- \+ small growth 1 – 20 cfu;
- ++ large growth 20 – 100 cfu;
- +++ very large growth above 100 cfu;

No.	place of swab collection	Imprint general microbial count	TSA medium general microbial count	SA medium presence of yeasts, dermatophytes and other fungi	Chapman medium	
					presence of *Staphylococcus sp*.	presence of *Staphyolococcus aureus*
1	Diving suit no. 1 inside, head	+++	+++	+++	+++	+++
2	Diving suit no. 1 inside, neck area	++	++	++	++	+
3	Wetsuit boot no. 1 inside	++	++	+	-	-
4	Wetsuit boot no. 2 inside	++	++	++	+	-
5	Flipper inside	++	++	++	+	-
6	Goggles, nose area	++	+++	++	++	+
7	Diving suit no. 2 inside, head	++	+++	+++	++	+
8	Diving suit no. 2 inside, armpit	–	+	+	+	-
9	Mask, mouth and nose area	++	++	+	++	+
10	Diving suit no. 3 inside, neck area	+++	+++	++	+++	++
11	Sock inside	++	+++	+++	+++	+
12	Diving suit no. 4 inside, neck area	++	++	++	++	+

Tab. 2 cont.

Sample collection from diving equipment surfaces on October 17, 2017 (before diving).

Research results
- \+ small growth 1 – 20 cfu;
- ++ large growth 20 – 100 cfu;
- +++ very large growth above 100 cfu;

No.	place of swab collection	Imprint general microbial count	TSA medium general microbial count	SA medium presence of yeasts, dermatophytes and other fungi	Chapman medium	
					presence of *Staphylococcus sp*.	presence of *Staphyolococcus aureus*
13	Diving suit no. 4 inside, lower sleeve part	++	+++	+++	+++	+++
14	Fleece undersuuit no. 1 inside, crotch area	++	+++	++	++	+
15	Fleece undersuit no. 1 inside, armpit	+	+	+	+	-
16	Fleece undersuit no. 2 inside, neck area	+++	+++	+++	+++	+
17	Fleece undersuit no. 2 inside, leg	+++	+++	+++	+++	++
18	Orange life jacket, neck area	++	+++	++	++	+
19	Mouthpiece no. 1	Not collected	+++	+++	++	+
20	Mouthpiece no. 2	Not collected	+++	+++	-	-

DISCUSSION OF RESEARCH RESULTS

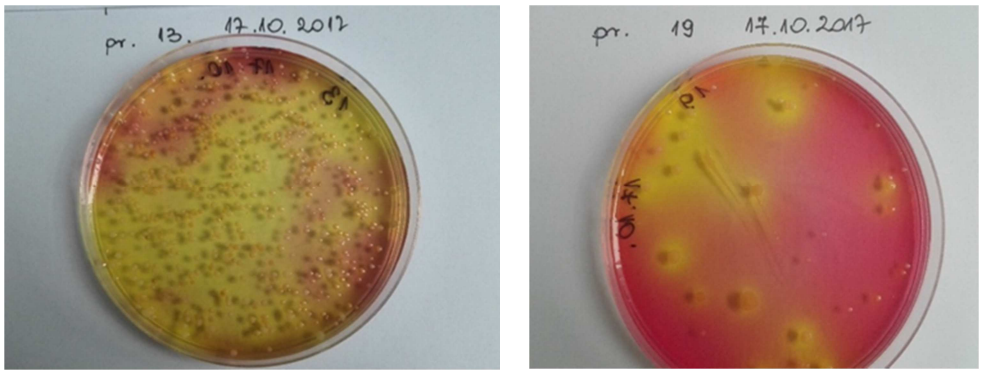

Fig. 1 Staphylococcus aureus.

- Sample no. 13, the swab was taken from the inside of a sleeve of a diving suit.
- Sample No. 19, the swab was taken from the inside of a mouthpiece.
- Staphylococcus aureus bacteria were isolated from Chapman medium.
- The bacteria of the Staphylococcus genus colonise the skin of every human being, constituting a natural, physiological bacterial flora, however it should be remembered that in altered conditions the same species may cause infections. Staphylococcus aureus mainly colonises the nasal vestibule and can be found in approximately 40% of people. Its presence in humans is referred to as carrier state.
- Staphylococcus aureus may be the cause of local infections, virtually affecting all tissues and organs, as well as generalised infections, often of a life-threatening character. The most common are purulent inflammations of the skin and soft tissues: furuncles, sties, impetigo, abscesses, purulent fungi and bone marrow inflammation, septic arthritis, endocarditis and pneumonia.

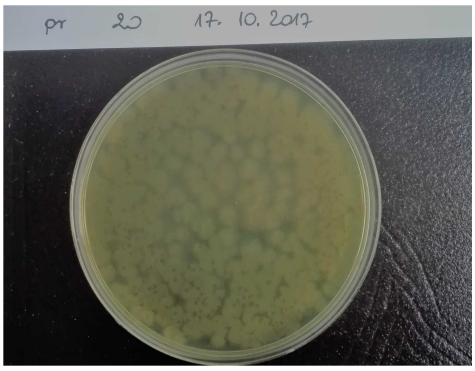

Fig. 2 Pseudomonas aeruginosa .

- Sample No. 20, the swab was taken from the inside of a mouthpiece; the *Pseudomonas aeruginosa* bacillus was isolated
- *Pseudomonas aeruginosa* causes, *inter alia*:
  - infections of the lower respiratory tract, which may take various courses, from asymptomatic carrier state, through mild tracheitis and bronchitis, to severe pneumonia;
  - otitis externa, particularly in individuals swimming in pools, known as "swimmer's ear";
  - inflammation of hair follicles, mainly in people with acne, especially after an exposure to water contaminated with these bacilli, e.g. in the swimming pool;
  - *pseudomonas aeruginosa* bacilli are naturally resistant to many antibiotics and easily acquire resistance to subsequent ones, which makes it very difficult to treat infections induced by these bacteria.

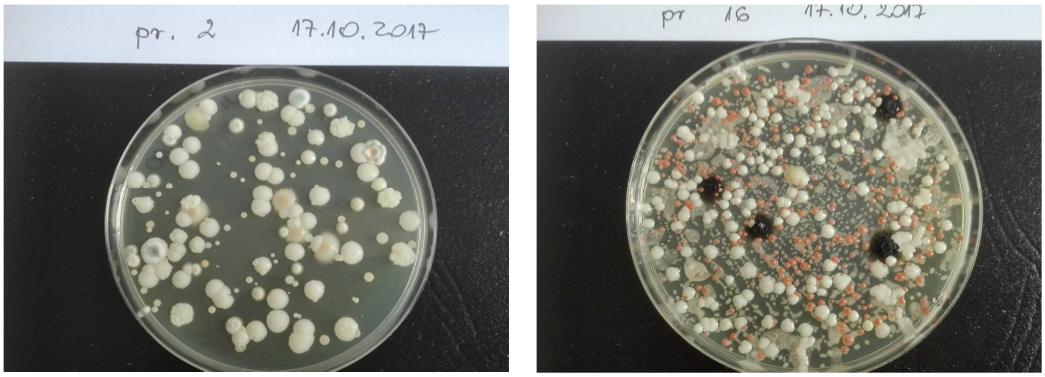

Fig. 3 Candida albicans.

- Sample no. 2, the swab was taken from the inside of a diving suit in the neck area.
- Sample no. 16, the swab was taken from the inside of a fleece undersuit in the neck area.
- Yeasts of the genus *Candida* were isolated from Saboraud medium.
- The major representative and at the same time the most frequently occurring pathogen is *Candida albicans*, which is a common commensal of the human gastrointestinal tract, however when it is present on the surface of the skin it is an opportunistic micro-organism.
- Candidiasis mainly affects the skin, mucous membranes and nails.
- The development of infection is favoured by a long-lasting antibiotic therapy, skin micro-injuries, skin maceration associated with excessive sweating, obesity, diabetes, alcohol abuse.

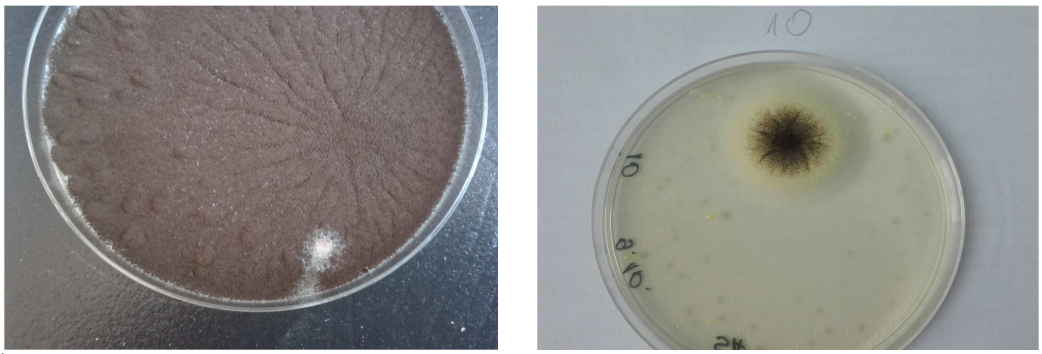

Fig. 4 Aspergillus Niger.

- Sample no. 10, the swab was taken from the inside of a wetsuit in the head area .
- *Aspergillus niger* was isolated from Sabouraud medium.
- Fungi of the genus *Aspergillus* are responsible for aspergillosis.
- The infection can be located almost in almost any tissue, however it mainly affects the respiratory system.

Fig. 5 Trichophyton.

- Sample no. 4, the swab was taken from the inside of a wetsuit boot.
- Sample no. 8, the swab was taken from the inside of the wetsuit in the neck area.
- Sabouraud agar culture allowed to isolate dermatophytes from the Trichophyton genus, which belong among disease-causing organisms.
- The most common dermatophytoses caused by this type of fungus affect the feet, nail plates, scalp, hair, and chin (in men).
- These conditions require long-term treatment and strict adherence to the principles of personal hygiene, as the infections are also transmitted by a direct contact or through the use of one's personal items.

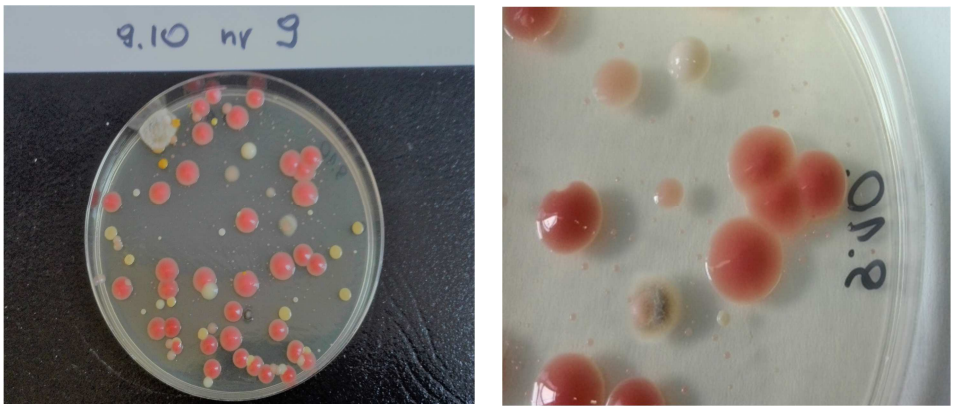

Fig. 6 Rhodotorula mucilaginosa.

- Sample no. 9, the swab was taken from the inside of a wetsuit in the head area.
- Yeasts from the *Rhodotorula* genus were isolated from the Sabouraud medium, i.e. common saprophytic microorganisms constituting a component of the physiological flora of human skin.
- However, recently numerous infections caused by *R.mucilaginosa*, *R.glutinis*, *R.minuta* species have been reported.

DISCUSSION OF RESEARCH RESULTS – GENERAL CONCLUSIONS

- None of the samples collected was sterile.
- *Staphylococcus aureus* bacteria were isolated from 80% of collected samples.
- *Pseudomonas aeruginosa* bacteria were isolated from samples taken from mouthpieces.
- The overwhelming majority of swabs and imprints resulted in a large or very large growth.
- Microorganisms from the genera *Candida*, *Cryptococcus*, *Rhodotorula*, *Trichophyton*, *Aspergillus* and many others were isolated from cultures on Sabouraud agar growth medium used in the cultivation of yeasts, dermatophytes and other fungi.

CONCLUSIONS

- The research confirmed that the diving equipment located in Diving Centres is the home of many different bacteria and fungi, including pathogenic ones.
- The vast majority of microbes found on the surfaces of wetsuits, diving suits, etc. are commensals (with some of them being opportunistic organisms). This fact allows us to realise that the surfaces of diving equipment are an excellent "transmission route" for various dermatoses and other diseases.
- In order to reduce the risk of infection the diving equipment that is used by various people should be subject to decontamination [9].
- The authors recommend decontamination with gaseous hydrogen peroxide which does not cause damage to equipment.

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