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Occupational exposure to air pollutants emitted from in situ burning of offshore oil spills: a large-scale field study

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ABSTRACT

Background: *In-situ burning (ISB) could be an effective cleanup method during spills. This study aims to study occupational exposure to pollutants emitted from offshore, large-scale ISB-experiments among personnel on vessels involved in ISB.*

Materials and methods: *Six experimental ISBs after release of 4.2–6 m^3 crude or refined oils were performed. Air measurements on three vessels were taken of particulate matter (PM) of different size fractions, polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds (VOC).*

Results: *One vessel was located upwind (about 80–140 m) from the burning oil while two work boats were positioned 200–400 m downwind. One of the work boats moved back and forth transverse to the smoke plume while the other followed the edge of the smoke plume downwind. During the burn period (28–63 min) the range of mean concentrations of $PM_{2.5}$ particles in the closest work boat downwind from the burn (0.068–0.616 mg/m^3) was considerably higher than in the upwind vessel (0.0198–0.029 mg/m^3) and in the work boat moving downwind at the edge of the visible smoke (0.007–0.078 mg/m^3). The particles were mainly in the $PM_{<1}$ fraction. In the work boat closest to the burn the mean concentration of particulate PAH and VOC was 0.046–0.070 ng/m^3 and < limit of detection –17.1 ppm, respectively.*

Conclusions: *The mean $PM_{2.5}$ levels in the closest vessel varied between 4 and 41 times higher than the 24-hour Norwegian Air Quality Criteria for the general population, indicating that the particulate exposure may impose a health risk for personnel up to 400 m downwind from an ISB. Exposure to VOC and PAH among crew on board vessels both upwind and downwind from the burning was low during these conditions. However, it is recommended that crew on vessels close to and downwind of smoke plumes from oil fires should use half-masks with P3 filters.*

(Int Marit Health 2022; 73, 1: 1–9)

Key words: oil cleanup, particles, particulate matter $(PM)_{2.5}$, polycyclic aromatic hydrocarbon, volatile organic compound

INTRODUCTION

As a potentially effective and cost-effective cleanup method during offshore oil spills [1], in-situ burning (ISB) could be a favourable alternative under the right circumstances. Efficiency of ISB can reach up to 95% for thick, non-weathered and non-emulsified oil slicks [2]. ISB may be a quick response method eliminating the need for storage and subsequent disposal of considerable volumes of oil and water recovered

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Table 1. Oil types, volumes, burn time and climatic conditions

Year	Sample	Oil	Oil type	Volume [m^3]	Burn [min]	Temperature[1] [°C]	Wind [m/s]	Relative[1] humidity [%]
2019	A	Oseberg blend	Light crude	6	63	14	4–5	77
	B	Oseberg blend	Light crude	5.6	44	11	4–5	95
	E	IF 180 — 1% S[2]	Heavy fuel	4.2	37	14	4–5	74
	F	Marine gas oil	Distillate fuel	6	28	15	6–7	75
2018	C	Oseberg blend	Light crude	6	43	10	6–7	81
	D	ULSFO	Residual fuel	5.8	48	11	4–5	65

[1]Information collected from Norwegian Centre for Climate Services for Heimdal gas processing centre located 30 km south of the in-situ burning burns. Mean values of the weather parameters are given for the respective burn periods; [2]Heavy fuel oil; ULSFO — ultra low sulphur fuel oil

mechanically. However, burning of oil also involve several adverse consequences, with air pollution being one of the most significant ones [3] and often also producing a viscous residue.

In-situ burning involves exposure of people in the close vicinity to acutely elevated levels of particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) [4]. Particulate matter produced due to incomplete combustion of oil prevails as the primary health concern among the air pollutants resulting from ISB [4] including the risk of detrimental effects on respiratory and cardiovascular systems [5]. Particulates are commonly divided into three categories based on their aerodynamic equivalent diameter (AED). Particles with an AED > 2.5 µm are commonly defined as "coarse", those between 0.1 and 2.5 µm as "fine" and < 0.1 µm as "ultrafine". Combustion of oil normally results in high concentrations of fine and ultrafine particles [3]. Over the years, the focus in PM-measurements has shifted towards the smaller particles as they are considered more hazardous to human health than the larger particles [6]. Acute health effects related to VOCs comprise irritation of airways, eyes and skin, while long-term exposure might, for some VOCs like benzene, lead to cancer [7]. PAHs, a collective term for compounds that consist of two or more aromatic benzene rings, are causally associated with lung, skin, and bladder cancer [8].

Previous research has focused on the dispersion [9, 10], physical properties [11] and chemical composition of the smoke plume from ISB [12, 13] as well as on the oil residues [14, 15]. Air pollution concentrations at sea level during offshore ISB have been estimated by use of exposure models based on measurements taken during the Deepwater Horizon oil spill in 2010 [16]. Mesoscale experiments [9, 17, 18] have also been helpful in modelling potential human exposure to air pollutants during ISB. Fingas [4] reported that although such models provide an important tool for assessing the impact of smoke both before and after a burn, they are not intended to replace monitoring. However, only few measured data on pollutants on surface vessels during offshore ISBs has been published [19].

This paper aims to investigate selected pollutants emitted from offshore oil fires as occupational hazards among workers on vessels involved in ISB, and to compare these exposures to relevant limit values. The study focuses on quantitative measurements of PM, PAHs and VOCs on vessels at sea level, emitted from in-situ burning of both crude and refined oils in large-scale experiments carried out in the North Sea.

MATERIALS AND METHODS

IN SITU BURNING EXPERIMENTS

The Norwegian Clean Seas Association for Operating Companies (NOFO) and the Norwegian Coastal Administration (NCA) normally perform annual "Oil on water" (OOW) verifications in Norwegian waters. In-situ burn experiments were performed in OOW 2018 and 2019 to verify ISB as a possible response method for the Norwegian continental shelf. These experiments were performed in cooperation with SINTEF Ocean Maritime Robotics AS, DESMI and the University of Bergen, and included use of fire-booms, drones for ignition of oil and air sampling [20]. This paper presents results from air measurements during totally six experimental ISBs with four different oil types. The oils were released in volumes of 4.2 to 6 m^3, and were contained into a fire-boom before ignited by use of a "Pyro-drone" using gelled mixture of diesel (80%) and gasoline (20%). Pre-weathered crude Oseberg Blend and three fuel oils; marine gas oil (MGO), an ultra-low sulphur fuel oil (ULSFO) and a heavy fuel oil (IFO 180) were used (Table 1). The main vessel was in charge of deploying and towing the fire-booms and releasing the oil. From the main vessel, two work boats (MOB-1 and MOB-2) were used for sampling surface oil, air monitoring, and recovery of burn residue. The personnel in the work boats were instructed to use half-masks with P3-filters during the experiments.

The same procedure was followed for experiments in OOW 2018 (two burns) and 2019 (four burns). During these burns, the oil was contained on the water surface by different fire-resistant oil booms towed in a U-formation. Air measurements were taken on three vessels: The main ves-

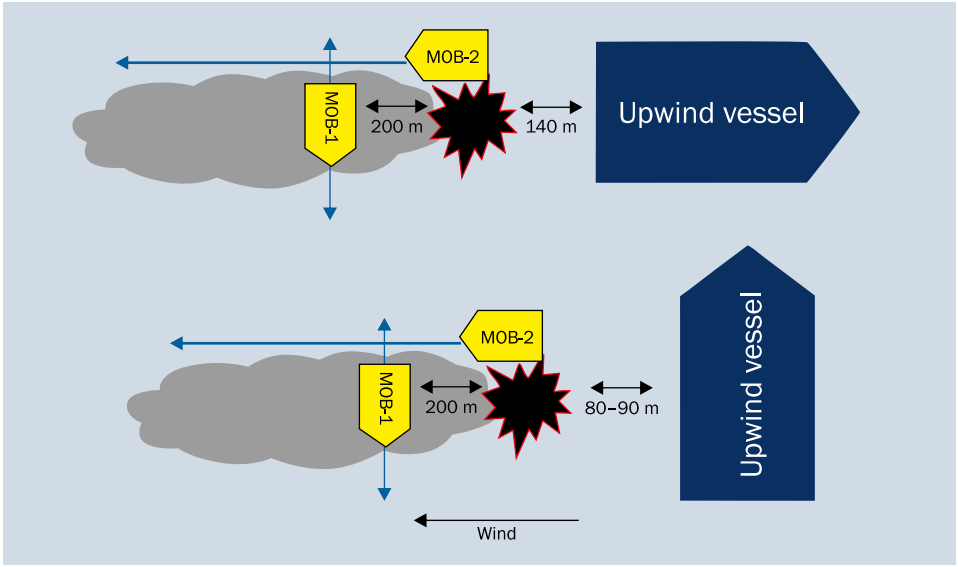

Figure 1. Illustration of the experimental setup in "Oil on water" (OOW) in 2018 (upper part) and 2019 (lower part). Black area indicates the burning oil and grey area indicate the smoke plume

Table 2. Analytes and sampling equipment

Location	Analyte	Units	Sampling method	Particle size [µm]
MOB-1[1]	$PM_{<1}$	particles/cm^3	P-Trak Ultrafine Particle Counter (8525)	0.02 to 1
	PM_1 $PM_{2.5}$ PM_4 PM_{10} "Total" dust	mg/m^3 mg/m^3 mg/m^3 mg/m^3 mg/m^3	DustTrak DRX Aerosol Monitor (8534)	0.1 to 15
	VOC	ppm	MiniRAE 3000 Photoionisation Detector	NA
MOB-2[2]	$PM_{2.5}$	mg/m^3	SidePak Personal Aerosol Monitor (AM510) + 2.5-micron impactor	0.1 to 2.5
Upwind vessel	$PM_{2.5}$	mg/m^3	DustTrak II Aerosol Monitor (8532) + 2.5-micron impactor	0.1 to 2.5
MOB-1 and upwind vessel	PAH	µg/m^3	37 mm cassette with a Teflon filter (SKC 225-1713) + XAD-2 sorbent tube (SKC 226-30-04) at 2.0 L/min (SKC pump)	"Total" dust fraction

[1]Work boat moving downwind transverse to the smoke plume; [2]Work boat moving downwind at the edge of the visible smoke; PAH — polycyclic aromatic hydrocarbons; PM — particulate matter; VOC — volatile organic compounds; NA — not available

sel located upwind (about 80–140 m) from the oil and two work boats (MOB-1 and MOB-2) located downwind (Fig. 1). MOB-1 was positioned about 200–400 m (the boat was in constant longitudinal movement) downwind from the oil burn and moved back and forth transverse to the smoke plume (Fig. 1). In OOW 2018, the distance between MOB-1's and Oseberg oil was about 400 m and gradually decreased to about 200 m as the burn progressed. The distance was considerably closer (200 m) upon the burning of ULSFO. In OOW 2019 MOB-1 was generally closer to the oil burns than in 2018, being kept at approximately 200 m behind the oil during all the burns. MOB-2 started each experiment out in the immediate vicinity of the oil and moved thereafter longitudinally to the plume all the way to the end of visible smoke. It kept its course along the edge of the smoke plume, transecting it 3–4 times for measurements directly under it.

AIR MEASUREMENTS

During the six ISBs, air measurements were taken outdoors on the main vessel located upwind from the burn and on the two work boats located downwind (Table 2). All measurements were carried out in the open sea (N59°59' E002°27') and under good weather conditions, i.e. wind

speed ≈ 4–7 m/s, air temperature ≈ 10–15°C, relative humidity ≈ 65–95% and no/negligible precipitation.

Particulate matter

Particulate matter of different particle-size fractions was sampled continuously with direct-reading instruments from TSI Inc. (Shoreview, Minnesota, USA); DustTrak DRX Aerosol Monitor (8534), SidePak Personal Aerosol Monitor (AM510) and P-Trak Ultrafine Particle Counter (8525) (Table 2). Sampling commenced upon ignition of each oil slick. Measurements were logged at 1 second intervals.

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons-sampling was undertaken in OOW 2018 on board the upwind vessel, as well as in the two downwind vessels MOB-1 and MOB-2. Two parallel samples were taken in MOB-1 during each of the two burns. In addition two parallel 12-hour samples including the two burns were taken on MOB-1, MOB-2 and the upwind vessel. PAHs were not measured in OOW 2019.

Polycyclic aromatic hydrocarbons was analysed in the "total" particulate fraction sampled by 37 mm closed-faced cassettes fitted with a Teflon 2 µm pore-size filter (SKC 225-1713), and in the vapour phase sampled by XAD-2 sorbent tube (SKC 226-30-04). The two sampling media were connected in series, and sampling was performed at a flow rate of 2.0 L/min using a SKC Sidekick Pump (Table 2). The particulates on the Teflon filter were analysed gravimetrically (mg on filter; limit of detection 0.1 mg ± 10%). Average air concentration (mg/m^3) was found by dividing by the air volume through the filter during the sampling period. Twenty-one PAH compounds (PAH21) in the particulate fraction and biphenyl and naphthalene in the vapour phase were analysed by gas chromatography/mass spectroscopy (GC/MS), with detection limits of 0.1 µg/m^3 (± 30%). The 21 PAH-compounds analysed were anthracene, benz[a]anthracene, benzo[a]fluorene, benzo[b]fluorene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[e]pyrene, benzo[ghi]perylene, dibenzo[a,h]anthracene, dibenzo[a,e]pyrene, dibenzo[a,h]pyrene, dibenzo[a,i]pyrene, dibenzo[a,l]pyrene, phenanthrene, fluoranthene, indenol(1,2,3-cd)pyrene, chrysene, pyrene, and triphenylene. PAHs were analysed according to the US NIOSH 5515, issue 2 [21] at Sintef Molab, Norway.

Volatile organic compounds

Volatile organic compounds levels were measured in OOW 2018 and 2019 with a direct-reading photoionisation detector (PID) MiniRAE3000 (RAE Systems Inc., San Jose, California, USA) located on MOB-1 only (Table 2). The PID, with a 10.6 eV lamp, was isobutylene-calibrated. Measurements commenced during oil release prior to ignition.

EXPOSURE LIMITS

The particle exposures were compared with the 8-hour Norwegian occupational exposure limit (OEL) for total dust/particulates of 10 mg/m^3 [22], the Norwegian Air Quality Criteria for $PM_{2.5}$-particles among the general population of 15 µg/m^3 (24 hours), and correspondingly 30 µg/m^3 for PM_{10} [23] as well as with the recently revised Air Quality Guidelines from the Word Health Organization (WHO) for $PM_{2.5}$ of 15 µg/m^3 (24 hours) [24].

The sum of the 21 PAHs (EPAH21) was compared with the Norwegian 8-hours OEL for the particulate fraction of 0.04 mg/m^3 while naphthalene and biphenyl in the vapour phase were compared with the OELs of 50 mg/m^3 and 1 mg/m^3, respectively. All the OELs need to be adjusted by a factor of 0.6 for a 12-hour workday [25]. There is no OEL for VOCs (C6-C10), but the 8-hours OEL for white spirits (C7-C12 with aromatic content < 22%) is 50 ppm.

DATA HANDLING

The arithmetic mean of the particle concentrations logged at 1 second intervals was calculated over the respective burning periods of the different oils (range: 28–63 min). In calculations of EPAH21 we used limit of detection/2 for PAH-compounds with concentration < limit of detection [26].

RESULTS

PARTICLES

Figure 2 shows typical results from continuous measurements of particle fraction $PM_{<1}$ in MOB-1 during burn of Oseberg Blend. A recognisable pattern of concentration peaks was seen as the boat traversed the smoke plume about 200 m downwind from the burn.

Measurement results during each of the burns are listed in Table 3. The particle concentrations were very low on the upwind vessel, while the levels measured in MOB-1 under the smoke were about ten times higher than in MOB-2 that moved in the outskirts of the visible smoke (Table 3).

The mean concentration of $PM_{2.5}$-particles in MOB-1 was higher in OOW 2019 (0.194–0.616 mg/m^3) compared to the levels in OOW 2018 (0.061–0.068 mg/m^3) (Table 3). The mean $PM_{2.5}$ levels in MOB-1 varied between 4 and 41 times higher than the 24-hour Norwegian Air Quality Criteria for the general population. Furthermore, the levels of $PM_{\leq 100}$ were low compared to the OEL for total dust of 10 mg/m^3. The mean levels in MOB-2 were considerably lower, and in OOW 2018 the $PM_{2.5}$-concentration during burning was close to background concentrations before burning. In the main vessel upwind the $PM_{2.5}$-concentration was close to background levels during all burns.

Among the oils the highest concentration was found for MGO followed by Oseberg (sample A), IF180 (E) and Oseberg

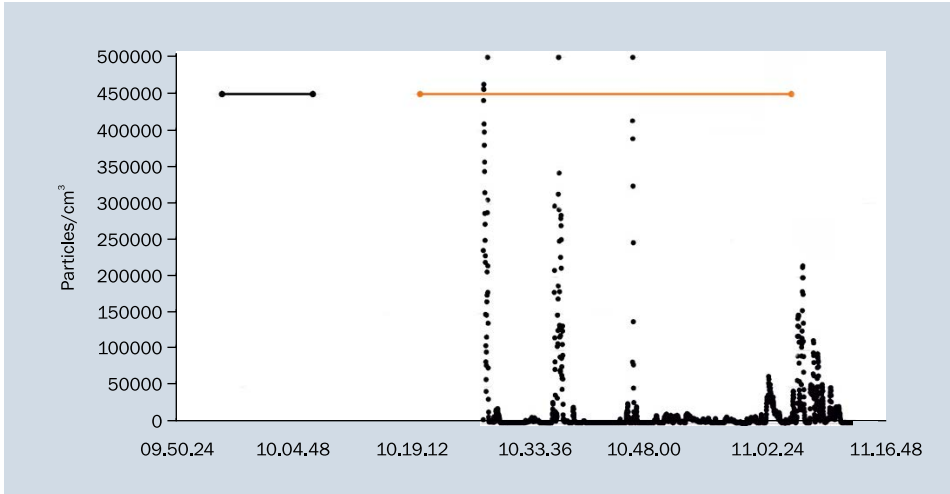

Figure 2. Example of continuous measurement with number of particles in the $PM_{<1}$-fraction (y-axis) from burning of Oseberg (red line) measured in MOB-1 in "Oil on water" (OOW) 2018. Black line indicated the oil release to sea. Time in hh.mm.ss (x-axis)

Table 3. Particle-concentrations of different size fractions and maximum volatile organic compounds (VOC)-concentration measured by direct reading instruments in "Oil on water" (OOW) 2018 and 2019

			Vessel							
			MOB-1					MOB-2	UW	MOB-1
			Particulate matter; Arithmetic mean [mg/m^3]							VOC-concentration [ppm]
			Particle size fraction							
Oil sample		Year	PM_1	$PM_{2.5}$	PM_4	PM_{10}	$PM_{\leq 100}$	$PM_{2.5}$	$PM_{2.5}$	
A	Oseberg blend	2019	0.421	0.424	0.426	0.431	0.432	0.048	0.022	Missing
B	Oseberg blend	2019	0.190	0.194	0.197	0.200	0.203	0.029	0.020	1.8
C	Oseberg blend	2018	0.067	0.068	0.069	0.071	0.071	0.007	0.018	0.4
D	ULSFO	2018	0.061	0.061	0.062	0.063	0.063	0.007	0.029	0
E	IF 180[1]	2019	0.240	0.245	0.250	0.261	0.265	0.054	0.020	2.5
F	Marine gas oil	2019	0.603	0.616	0.626	0.647	0.653	0.078	0.026	17.1

[1]Heavy fuel oil; PM — particulate matter; ULSFO — ultra low sulphur fuel oil; UW — upwind vessel

(sample B) (Table 3). Sample A and B (both Oseberg blend) were collected at the same distance from the burning oil, but the burn time of A was over 50% longer than B, and the average PM concentration for sample A was about 2.2 times higher than for sample B.

There were only small differences between the different particle size fractions from PM_1 to $PM_{<100}$ on all vessels. The highest peak concentration of the different particle size fractions was measured when MOB-1 was located directly under the smoke cloud as indicated by the peaks of the smallest particles ($PM_{<1}$) (Fig. 2).

POLYCYCLIC AROMATIC HYDROCARBONS

The results in Table 4 show small differences in PAH-concentrations between the vessels, and very low levels compared to Norwegian OELs. This includes both the full-shift (12-hour) measurements and the measurements that were taken during the actual release and burning of the two oils Oseberg and ULSFO. The results from the 12-hour measurements of EPAH21 (0.011 µg/m^3) corresponds to < 0.03% of the Norwegian OEL, while the highest measured concentrations of naphthalene (1.5 µg/m^3) and biphenyl (0.19 µg/m^3) detected were < 0.003% and < 0.02% of the respective OELs.

VOLATILE ORGANIC COMPOUNDS

Recorded levels of VOCs in MOB-1 were low during release and burning of the oils. Peaks of VOC concentrations as measured during oil release and ISB are listed in Table 3. These peaks were registered due to oil leakage from the fire booms prior to ISBs. Non-detectable or negligible values were detected during all ISBs. The peak levels indicated in Table 3 are well below the 8-hour OEL for white spirits (C7-C12) of 50 ppm.

Table 4. Results from measurements of polycyclic aromatic hydrocarbons on three different vessels in "Oil on water" (OOW) 2018

Location/vessel	Sample type	Oil sample	Sampling time [min]	Naphthalene (vapour) [µg/m^3]	Biphenyl (vapour) [µg/m^3]	ΣPAH21[1] (particulate) [µg/m^3]
Main vessel/upwind	12-h	C + D; Oseberg blend+ULSFO	731	1.50	0.180	0.010
Main vessel/upwind	12-h	C + D; Oseberg blend+ULSFO	731	1.50	0.190	0.011
MOB-2	12-h	C + D; Oseberg blend+ULSFO	722	0.26	0.039	0.010
MOB-2	12-h	C + D; Oseberg blend+ULSFO	722	0.33	0.050	0.010
MOB-1	12-h	C + D; Oseberg blend+ULSFO	615	0.47	0.051	0.012
MOB-1	12-h	C + D; Oseberg blend+ULSFO	615	0.55	0.046	0.011
MOB-1	Oil release + burn	C; Oseberg blend	68	0.50	0.040	0.060
MOB-1	Oil release + burn	C; Oseberg blend	68	0.82	0.049	0.070
MOB-1	Oil release + burn	D; ULSFO	82	0.82	0.026	0.049
MOB-1	Oil release + burn	D; ULSFO	82	1.00	0.030	0.046

[1]The sum of 21 polycyclic aromatic hydrocarbons (PAH) compounds in the particulate fraction; ULSFO — ultra low sulphur fuel oil

DISCUSSION

The concentration of $PM_{2.5}$ particles in the closest vessel, located about 200–400 m downwind from the burn, was well above the Norwegian Air Quality Criteria and the guideline from WHO, and considerably higher than in the upwind vessel as well as in work boat that moved in the outskirts of the visible smoke. A major part of the measured particulates was in the $PM_{<1}$ particle fraction. The concentration of PAH on the vessels both upwind and downwind from the burns was very low. Furthermore, negligible concentrations of VOCs were measured in the closest vessel during burning.

The mean concentration of $PM_{2.5}$-particles in the work boat moving 200–400 m downwind from the burn (range: 0.068–0.616 mg/m^3) was somewhat higher than measured at ground-level 500 m from the Newfoundland offshore burn experiment of 29–48 m^3 oil (0.05–0.13 mg/m^3), but it was considerably lower than in a remotely controlled vessel located only 100 m downwind from the burn (12.3–14.3 mg/m^3) [19]. In 14 onshore mesoscale ISB-experiments of crude oil (1.3–11.8 m^3) in Mobile, Alabama the mean concentration of particles at ground level stations at 66 m downwind was 0.299 mg/m^3 but varied considerably (range: 0.03–3.1 mg/m^3) due to high variability in microscale winds and turbulence [27]. Variations in the positioning of the ground/sea level monitoring stations/vessels relative to the burn and differences in weather conditions will contribute to the variability in measured particle concentrations. Care should also be taken when comparing results from the different studies as different monitoring instruments have been used. In the NOBE and Mobile studies the RAM (real-time aerosol monitors) instrument differed in specifications from the particle monitor presently used, including the cut-point for particle size (0.1–20 µm vs. 0.1–100 µm).

The difference in particle concentrations between the three vessels in our study indicates that the particles are concentrated mainly within the boundaries of visible smoke, and that there is a negligible effect on the air quality from the burning on vessels placed upwind from the smoke plume. The generally lower concentrations in OOW 2018 compared to 2019 in MOB-1 is presumably due to the shorter distance to the burn in OOW 2019 (about 200 m) compared to OOW 2018 when the distance varied between 200 m and 400 m. Thus, particulate concentrations declined with increasing distance from the burn, and it also decreased relatively short time after the fire was extinguished. Similar findings have also been reported in Buist et al. [28] and are in accordance with the suggestion by Fingas et al. [18] that particulate matter is a matter of health concern only close to the fire and directly under the plume.

In situ burning of MGO was associated with 2–3 times higher $PM_{2.5}$-concentration in the closest vessel than when burning the crude oil Oseberg and the heavy fuel oil IF180. In line with this, Fingas [4] reported that the concentrations of particulates in emissions from burning diesel are approximately four times that from similar sized crude oil burns at the same distance from the fire. One may speculate whether the higher burning efficiency of MGO (< 90%) than for Oseberg (80–91%) and IF180 (< 60%) [20] could be one of the reasons for this finding. On the other hand, the difference in particle concentration between the two samples of Oseberg blend in OOW 2019 might be associated with the longer burning time and larger volume of oil in the sample with highest $PM_{2.5}$-concentration.

The $PM_{2.5}$ levels on the closest vessel in OOW 2018 and OOW 2019 varied between 4 and 41 times higher than the 24-hour Norwegian Air Quality Criteria for the general popu-

lation. However, the levels of $PM_{\leq 100}$ were low compared to the OEL for total dust of 10 mg/m^3. Independent of the oil type, the small difference between the particle size fractions from PM_1 to $PM_{<100}$ indicate that the smoke mainly consists of particulate matter in the < PM_1 size fraction that includes the ultrafine particles. These findings are in accordance with results from oil burning during the Deepwater Horizon oil spill where the particle size in smoke from burning was in the range of 0.1–1.0 µm, with a peak at about 0.4 µm [29]. Similar results were found in the NOBE-burnings where the particle size was mainly in the range of 0.1–1.0 µm, with a peak at 0.3 µm [3]. During the last years there has been increased focus on these smallest particles (< 1 µm) as they may have adverse effects not only on the lungs, but also on the heart and circulatory system, at relatively short exposure periods [30]. In addition to having a larger, porous surface area, which makes them prone to further adsorption of harmful substances, they also dominate over large particles in particle number concentrations [31]. However, these particles do not yet have any OEL or air quality criteria. Nevertheless, preventive measures to reduce exposure to such particles should be considered to reduce potential health effects. Thus, crew on vessels close to and downwind of smoke plumes from oil fires should use half-masks with P3-filters. Laboratory studies have shown that percentage penetration for P3-filters was < 0.03% for particles with a medium size of 0.238 µm, which is typical size for smoke particles from burning oil [32]. Burning of MGO was associated with the highest mean particle concentration (0.6 mg/m^3). When using a percentage penetration of 0.05% for typical particle sizes (0.2–0.4 µm) in this type of smoke the particle concentration inside the mask would be about 0.3 µg/m^3, which is considerably lower than the $PM_{2.5}$ Norwegian Air Quality Criteria for the general population and indicates that when used properly this type of respiratory masks should provide adequate protection for the personnel. However, the real protection would probably be lower since the penetration of particles through the filter is not the only limiting factor since leakages between the skin and the mask may contribute significantly to the inhaled particle concentration. Such particle leakage should be reduced as far as possible through education, training and fit testing.

The air concentration of PAH was very low compared to OELs, and there were only small differences in the full-shift levels of PAH between the three vessels even though the direct reading instruments showed larger particle-concentrations in MOB-1 than in the two other vessels during burning. Particulate PAH is bound to the soot-particles, and when moving away from the smoke plume the exposure to PAH is expected to decrease similarly as reported for the particles. Since the concentrations in all vessels were < 0.03% of the Norwegian OELs for the respective PAH-compounds it is concluded that personal exposure to PAH among crew on board vessels both upwind and downwind from the burning was very low during these conditions with relatively short burning time. Our findings are in accordance with the results from PAH measurement at sea-level during the NOBE burns reporting low air concentrations of PAH [19] as well as 66 m downwind from the onshore Mobile ISBs [27] and 30 m downwind from oil burns in Calgary [33]. However, different sampling methodology and sets of analysed PAH components precludes direct comparison of concentration levels.

The low levels of VOCs on the vessels were expected since the oils used were either a pre-weathered crude oil or different fuel oils, and not fresh crude oils with high levels of volatile hydrocarbons. The highest peak level of VOC was found for the distilled fuel oil (MGO), which is associated with the higher volatility and lower viscosity of this oil compared to the other oils tested. There is no OEL for VOCs, but even the peak levels measured during the burnings were well below the 8-hour OEL for white spirits of 50 ppm (275 mg/m^3). Previous studies also found VOCs at low levels as close as 30 m to 150 m downwind from the fire, suggesting they are not a major health concern [2, 33]. Evaporation of VOCs from an unburned crude oil is considered more hazardous than VOCs produced in combustion [2, 28]. Previous studies [34, 35] have shown that personnel located close and downwind from a bulk spill of fresh light crude oil at sea can be exposed to benzene levels exceeding the OEL during the initial stages of the spill. In such cases half-face air purifying respirators with a combination of a particle filter and an organic vapour cartridge, A2 should be used to prevent biological uptake of benzene.

The relative position of the vessel to the oils, in addition to the weather/climatic conditions, is among the largest sources of uncertainty in the presented measurements. Despite logistical constraints and unpredictable weather associated with field experiments in open sea, the measurements were carried out in a relatively narrow weather window with low wind speed (4–7 m/s), moderate air temperature (10–15 °C) and no or negligible precipitation. Relative humidity varied in the range 65–95%, and according to Jayaratne et al. [36] the DustTrak instrument overestimates the particle concentration due to particle growth by water absorption when relative humidity is above 78%, with an about 50% overestimation at 90% relative humidity. In our study relative humidity exceeded 78% in two of the burns (81% and 95%, respectively). At the highest relative humidity (95%) the particle concentration was lower than when burning the same oil at a relative humidity of 77%, indicating that other factors had considerably more impact on the particle concentration. Furthermore, the positioning of the vessels was largely the same for the individual

burns. However, at the start of the burns the most exposed work boat was closer to the burn in 2019 than in 2018, which is reflected in a higher particle concentration in 2019 than in 2018. Our results are based on relatively few experiments, and more detailed studies under similar conditions are needed to study potential differences in exposure between oil types. We have compared the results of our measurements of particles and PAH to OEL's and Air Quality Criteria set for 8 or 24 hours, although, in most cases, our measurements had considerably lower duration. Nevertheless, such comparison still gives an indication on when precautions should be taken when exposed to emissions from ISB.

CONCLUSIONS

The findings show that the particles from the burns are mainly in the $PM_{<1}$ fraction, which includes the ultrafine particles (< 0.1 µm). The higher particle-concentration when burning distillate fuel oil compared to crude oil and heavy fuel oil might be associated with the higher burning efficiency. The particles are concentrated within the boundaries of visible smoke. At the measured concentrations they may impose a health risk for personnel up to 400 m downwind from an ISB operation, but not for the personnel upwind. The mean exposure to PAH and VOC among personnel on board vessels both upwind and downwind from the burning was low during these conditions, and the concentrations will most likely not reach OEL at sea level. Nevertheless, since PAH is carcinogenic the exposure should be kept at low as possible. We recommend that personnel close to and downwind of smoke plumes from oil fires should use half-masks with P3 filters to prevent inhalation small particles (< $PM_{2.5}$) and particulate PAH. Efficient use of such masks requires training of the users and proper fit testing.

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Evaluation of occupational health management status and safety issues of the small-scale fisheries sector in Bangladesh

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ABSTRACT

Background: *Small-scale fishing is one of the most precarious occupations, with high rates of threats and hazards. The present study was undertaken to evaluate the health hazards and safety issues of fishers involved in small-scale fisheries (SSF).*

Materials and methods: *Fifty SSF fishers (n = 50) were surveyed by using a pre-tested questionnaire between October 2019 and March 2020 at the lower Meghna River in the northern tip of the Bay of Bengal, Bangladesh.*

Results: *Results revealed that 56% of SSF fishermen belong to a nuclear family, and 42% completed primary education. Forty per cent had an annual income of between 1,000 and 1,500 USD. Seventy-six per cent of fishermen were found to suffer from fever, and 72%, and 60% from diarrhoea and skin diseases over the last 5 years (2015–2020), respectively. During fishing, 78% of fishermen also suffered from red-eye problems, dizziness, and headache, and 68% struggled with musculoskeletal complaints during the last 5 years. Extreme cyclonic occurrences and sudden storms were experienced by 66% and 32% of fishermen, respectively, during the last 5 years. Local pharmacies were visited by 46% of fishermen for treatment due to ease of access. Sixty-four per cent of participants applied their local indigenous knowledge to treat health-related problems. Twenty-eight per cent and 32% of fishermen used a first aid box and stored medicine on board, respectively.*

Conclusions: *Most of the fishers are in great risk of medium- to high-range danger while fishing in the SSF sector in Bangladesh. Many countries have developed protocols for safe and responsible fishing. In Bangladesh, adequate attention is needed for the sustainable development of the SSF sector.*

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Key words: occupational health hazards, small scale fisheries (SSF), health and safety issues, coastal fishermen, Bangladesh

INTRODUCTION

The global catch generated by fisheries is 96.4 million metric tons (MT), which is mostly driven by marine ecosystems [1]. Globally, 4.56 million fishing vessels (from small, undecked and non-motorised boats up to large industrial vessels) and 59.51 million individuals are engaged (on a full-time, part-time, or incidental basis) within the essential segment of capture fisheries (39.0 million individuals) [1]. Fisheries support nourishment, livelihoods, trade, and food security [2, 3]. In Bangladesh, total marine fisheries production is 0.65 million MT, whereas artisanal/small-scale fisheries (SSF) contribute 82% of the total yield, and large-

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scale fisheries contribute the rest, with an annual growth rate of 2.71% [4]. Fisheries and other natural-resource-based livelihoods are traditionally very important to coastal communities [5]. In coastal Bangladesh, around 484,000 families rely upon fishing [6]. In excess of 12% of the 165-million population of Bangladesh rely upon fisheries- and aquaculture-related activities for their livelihoods [6]. Bangladesh produces 86% of the world's total hilsa (*Tenualosa ilisha*) [7]. Hilsa is the species making up the highest proportion (around 12%) of the nation's total fish production [4]. Half a million fishermen in Bangladesh are involved in hilsa fishing [8].

Small-scale fisheries use low-tech fishing gear, such as hooks and line, nets, and traps, and dominate multi-species coastal fisheries [9, 10]. The intensity of any type of gear used is determined by the population of target fish [11]. Most people are unaware of how important small-scale fishing (within 40 m depth) is as a source of livelihood, food security, and national income. Small-scale fishermen use small fishing vessels with low capital investment and account for 90% of the 15 million people who participate in coastal and ocean fishing. Fishing is considered one of the oldest [12] and probably most daring occupations, with a high threat of professional hazard, specifically traumatic injury [13] and endemic diseases [14, 15]. Work-related injuries are more common in fishing than in any other occupation [16]. According to International Labour Organization and Food and Agriculture Organization, 7% of all labourer mortalities occur in the fishing industry [17]. These casualties and serious wounds put fishing as a profession at the top of the list of risk hierarchy. In a recent study, sea fishing mortality was recorded as 0.08% per year [18]. This is mainly due to the insecure working atmosphere [19]. Mortality and sickness among fishermen continue to be unsatisfactorily high, and fishermen and their families are regularly at risk due to their livelihood and social security frameworks [20]. Storms, floods, and climate change are only a few of the environmental, economic, and societal threats that many fishermen have faced over the years [21, 22]. Small-scale fishermen ignore high temperatures, lack safety measures during rainy season and tides, and have little or no sustenance during the fishing period, so they fight for their livelihoods [11].

Occupational health and safety is a multidisciplinary field that focuses on the security, health, and well-being of individuals who work. An occupational health and safety programme's purpose is to promote a safe and healthy working environment. In a developing country like Bangladesh, fishermen are one of the most vulnerable groups due to their livelihood opportunities [23]. Proper and available information on occupational health management and safety issues of SSF fishermen is still inconsistent in Bangladesh. There are no occupational health services or obligatory health screening for these small-scale fishers, and occupational accidents and diseases are under-reported, as most of the fishers in this division are uninsured. Consequently, the present study was conducted to evaluate and identify the occupational health hazards affecting small-scale fishermen and their care-seeking behaviour related to these health difficulties.

MATERIALS AND METHODS

STUDY SITE AND PERIOD

Meghna is one of the largest rivers in Bangladesh and is interconnected by different channels. The present investigation was performed with the SSF fishers working adjacent to the lower Meghna River in the northern tip of the Bay of Bengal, Bangladesh (Fig. 1). The study area has abundant riverine fisheries resources. The data was collected between October 2019 and March 2020.

SELECTION OF PARTICIPANTS

There were no accessible measurements or records on occupational hazard components and security appraisal of the SSF sector. Data was randomly collected from 50 small-scale fishers (n = 50) on the site of landing.

QUESTIONNAIRE PREPARATION AND VALIDATION

The questionnaire was developed after a detailed literature review of personal experiences. In the neighbouring Lakshmipur district, piloting was carried out in a similar setting for SSF. During the pilot, a total of 10 small-scale fishermen participated. The questionnaire was reframed and retained chronology after piloting to collect data in a clear way. For easy processing, the questionnaire was produced in English and then translated into Bengali, the local language.

DATA COLLECTION

Information was collected during a face-to-face interview, utilising a semi-structured questionnaire after obtaining written consent. The questionnaire was partitioned into three segments. The primary area included data about socio-economic and demographic characteristics. The second section was outlined to gather information about the occupational attributes. The third section of the review was laid out to assemble information about occupational hazards and safety associated with their work that the interviewed crew endures. Participants were voluntarily interested in the research and were promised confidentiality after being given specifics of the study.

DATA ANALYSIS

The collected data were summarised and scrutinised carefully. After information collection, the data were aggregated and analysed using descriptive statistical tools using

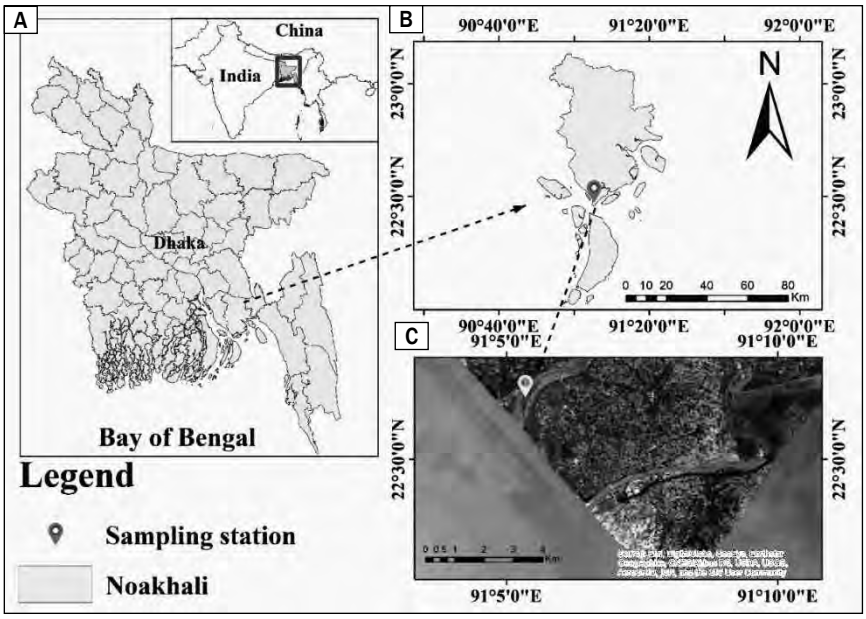

Figure 1. Geographical location of the study area; **A.** Map of Bangladesh; **B.** Map of Noakhali district; **C.** Satellite view of Chairman *Ghat* fish landing centre

MS Excel 2016. ArcGIS (version 10.3) was used for mapping the sampling stations.

RESULTS

SOCIO-ECONOMIC AND DEMOGRAPHIC CHARACTERISTICS

Socio-economic and demographic characteristics included the age, family size and type, educational status, drinking water access, sanitary, electricity and housing facilities, and income of fishers. Forty-four per cent of small-scale fishermen were between 20 and 30 years of age, and 30%, 18%, and 8% were aged between 31 and 40 years, older than 40 years, and younger than 20 years, respectively (Table 1). More than half (56%) were from a nuclear family and the rest from joint family settings. Among the respondents, 58% of fishermen belonged to a medium-sized family, which consisted of 5–8 members. The study found that 42% of small-scale fishermen completed primary-level education, 20% were illiterate, and 34% could not complete primary education. Forty-eight per cent of fishermen lived in the *katcha* house, whereas only 12% of fishermen lived in the *pucca* house (Table 1). Forty-eight per cent of fishermen have their own tube-well for drinking water. In SSF, 94% of fishermen used tube-well water in the boat during fishing, which was carried by container or bottle. Thirty-four per cent of small-scale fishermen had sanitary toilet facilities at home. On the other hand, there were no sanitary facilities on board and they used an open system. Sixty per cent of fishermen had electricity facilities, whereas 16% and 24% used solar energy and kerosene in their households, respectively. Most of the small-scale fishermen (40%) had an annual income of between 1,000 and 1,500 USD (Table 1).

OCCUPATIONAL CHARACTERISTICS

Fifty-two per cent of fishermen engaged with agriculture as their secondary occupation (in terms of time) during banning periods and lean seasons (months), whereas it was 18%, 6%, and 6% for day labourer, rickshaw puller, and driver (Auto, CNG), respectively (Table 2). Sixteen per cent of fishermen had more than 30 years of fishing experience. Most of the fishermen (84%) used to fishing more than two times per month. This frequency depends on the vessel type, engine capacity, and duration of each trip. Large boats stayed in the river for longer times compared to medium and small boats. Fishing trawlers stayed around 10 to 13 days, whereas *tempo* stayed for 5–7 days, and *choto tempo* made daily trips. Seventy-two per cent of fishermen fished all year except for the banning period, whereas only 18% of fishermen fished in the peak season (September to November). The present findings showed that 52% of fishermen had their own boat: 8% were single owners and 44% jointly owned their boats. The remaining 48% of fishermen worked under *mohajan*, who rent boats to the fishers or recruit fishers on a monthly/seasonal basis. Forty per cent of fishermen had *tempo* or *chandi* boat, whereas 32% and 28% had *choto tempo* and trawler, respectively. Four categories of gear, especially net, were used by the fishermen in the study area to catch fish. Among all SSF fishermen, 34% had *chandi jal*, 28% had *char suta jal*, 22% had current *jal*, and 16% had *lal jal* (Table 2).

Table 1. Socio-economic and demographic characteristics of small-scale fisheries at the lower Meghna river in Bangladesh (n = 50)

Variables	Sub-category	Frequency (n)	Percentage (%)
Age structure	< 20 years	4	8
	20–30 years	22	44
	31–40 years	15	30
	> 40 years	9	18
Family type	Nuclear family	28	56
	Joint family	22	44
Family size	Small family (< 5)	6	12
	Medium family (5–8)	29	58
	Large family (> 8)	15	30
Educational status	Illiterate	10	20
	Primary incomplete	17	34
	Primary complete	21	42
	Secondary	2	4
Housing condition	*Pucca*	6	12
	Semi-*pucca*	20	40
	Katcha	24	48
Drinking water facilities at household	Own	24	48
	Neighbour	12	24
	Government	14	28
Drinking water facilities on board	Tube well	47	94
	River	3	6
Sanitary facilities at household	Sanitary	17	34
	Closed	28	56
	Hanging	5	10
Electricity facilities	Electricity	30	60
	Solar	8	16
	Kerosene	12	24
Income (USD/year)	Less than 1000	5	10
	1000–1500	20	40
	1501–2000	18	36
	Above 2000	7	14

OCCUPATIONAL HEALTH HAZARDS

Seventy-two per cent of small-scale fishermen suffered from diarrhoea, and 76% suffered from fever. Sixty per cent of fishermen suffered from skin disease (rashes, itching, and scabies types) in the study area (Fig. 2).

The study found that 78% of the fishermen were exposed to accidents during fishing in the last 5 years, 52% of them reported injuries due to accident, and 38% of the fishermen were exposed to sunburn (Fig. 3). Seventy-eight per cent of small-scale fishermen suffered from dizziness and headache, and 68% suffered musculoskeletal complaints due to fishing.

HAZARDS DURING FISHING

Fishermen principally confront tropical cyclones while fishing, mainly in the rainy season. They also confront overwhelming rainfall and ocean storms, which can obstruct their daily activities and can be life threatening. During bad weather conditions, fishermen avoid deep-sea fishing and fish near the shoreline, as per government instruction. The risk during the rainy season is critically high compared to the winter and summer seasons due to natural calamity. About 66% of fishermen said that they confronted extreme cyclonic occurrences while fishing, whereas 32% have faced sudden storms caused by deep-sea depression. Fishermen lose their fishing nets and other equipment during these natural hazards. Fourteen per cent of fishermen confronted heavy rain, and 38% of fishermen faced bad weather conditions in the last 5 years (Table 3). Fourteen per cent of fishermen faced temporary or fatal loss of way due to impenetrable fog or a cloudy environment with unfamiliar wind direction.

Table 2. Frequency distribution of some occupational characteristics of small-scale fisheries at the lower Meghna River in Bangladesh (n = 50)

Variables	Sub-category	Frequency (n)	Percentage (%)
Secondary occupation	Agriculture	26	52
	Day labour	9	18
	Rickshaw puller	3	6
	Driver (Auto*, CNG**)	3	6
	Unemployed	9	18
Experience in fishing	< 10 years	19	38
	10–20 years	16	32
	21–30 years	7	14
	> 30 years	8	16
Frequency to go fishing per month in a season	One time	2	4
	Two times	6	12
	> two times	42	84
Types of fishermen	Seasonal	14	28
	Year-round	36	72
Fishing boat	*Choto tempo*	16	32
	Tempo or *Chandi*	20	40
	Fishing Trawler	14	28
Fishing gear	*Chandi jal*	17	34
	Char suta jal	14	28
	Current *jal*	11	22
	Lal jal	8	16

*Motorised version of pulled rickshaw; **CNG — compressed natural gas fuel-based vehicle

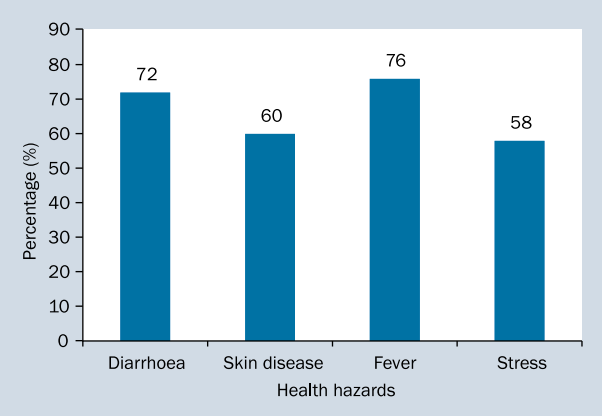

Figure 2. Occupational health hazards of the small-scale fisheries fishers at the lower Meghna River in Bangladesh in last 5 years (2015–2020) (n = 50)

BEHAVIOUR FOR SEEKING HEALTHCARE

Table 4 shows that the percentage of fishers who visit a doctor was 68%. Most of the small-scale fishermen like to visit a local pharmacy (46%) and *Kobiraj* (16%) compared to the government hospital (10%) and private hospital (6%) for their treatment (Table 4). Twenty-eight per cent of fishermen visit the doctor only for diarrhoea, whereas 22% and 18% visit for vomiting and fever, respectively. Diarrheal disease mainly occurred due to the poor-quality drinking water on board. This study also revealed that the maximum number of respondents did not take medicine from specialists until they were confronted by serious illnesses.

OCCUPATIONAL HEALTH SAFETY

Respondents were asked about their choices regarding methods they have taken to manage health risks. Sixty-four per cent of fishermen used local indigenous knowledge for treating health-related issues (Table 5). According to the findings, 32% of fishermen stored medicine (Paracetamol™ as painkiller, Omeprazole® to treat acidity, Ranitidine® to treat stomach ulcers), and 28% of fishermen used first aid (bandage, cotton, Savlon®, ORsaline-N®, Salve® — antiseptic) on board. Before starting the journey for fishing, 68% of fishermen took floatation aids such as a lifejacket, raincoat, or extra fishing net ball for use, if necessary, in any lifesaving situation. Seventy-six per cent of fishermen used a mobile phone to get regular updates on weather forecasts and contact other fishermen and family members on board, in case of sudden catastrophes.

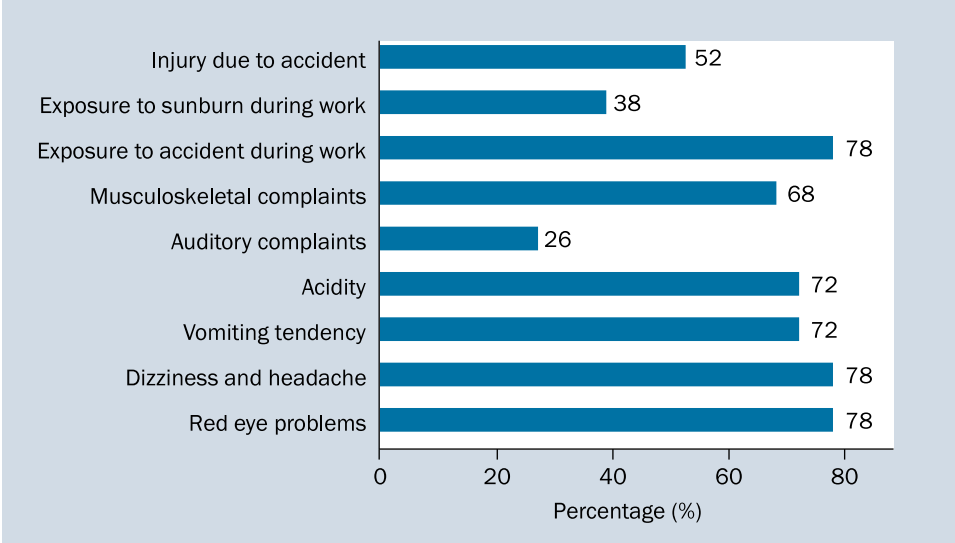

Figure 3. Other occupational health hazards related to small-scale fisheries in last 5 years (2015–2020) in Bangladesh (n = 50)

Table 3. Hazards associated with fishing of the small-scale fisheries fishers at the lower Meghna River in Bangladesh in last 5 years (2015–2020) (n = 50)

Variables	Sub-category	Frequency (n)	Percentage (%)
Accidents associated with the natural calamity	Cyclone	33	66
	Heavy rain	7	14
	Foggy	14	28
	Bad weather	19	38
	Storms	16	32
Accidents associated with navigation	Loss of power	8	16
	Loss of way	7	14
	Collisions	5	10
Accidents associated with fishing operations	Injuries from fish	3	6
	Injury by deck machinery and equipment	12	24

DISCUSSION

SOCIO-ECONOMIC AND DEMOGRAPHIC CHARACTERISTICS

Age is a critical variable in fisheries activities. The present study showed that a young age group (44%) was dominant, which is similar to the findings of Pravakar et al. (2013) [24] in the Shahrasti sub-district under Chandpur district and the findings of Minar et al. (2012) [25] in the Kirtonkhola River near the town of Barisal. Family size has considerable influence on the income and expenditure of the family. In the case of the fisher community, it was found that most fishermen had nuclear rather than joint families, which was similar to the findings of Dey et al. (2010) [26]. The educational level of Bangladeshi fishermen is generally very low [27]. Only 42% of small-scale fishermen completed primary-level education. The present study found that most of the families are unable to maintain the educational expenses of their school-age children. Low levels of education are an obstacle for the implementation of the fishing sector's safety and health programmes. The study indicates that the housing conditions of the small-scale fishermen were very poor. 48% of fishermen lived in the *katcha* house, which was similar to the findings of Sunny et al. (2019) [28]. Most of the fishermen (40%) had an annual income of between 1,000 and 1,500 USD. Pravakar et al. (2013) [24] found that most fish farmers (34%) earned between 900 and 1,200 USD per year, which is similar to the present study. Fishermen were paid a percentage of the harvest value, so their incomes were dependent on the number of fish caught. As a result, if boat owners decided to leave their boats offshore, the harvest was reduced, resulting in lower salaries and even job losses.

Table 4. Health care seeking behaviour of the of the small-scale fisheries fishers at the lower Meghna River in Bangladesh in last 5 years (2015–2020) (n = 50)

Variables	Sub-category	Frequency (n)	Percentage (%)
Visit to doctor		34	68
Doctor's types	Government hospital	5	10
	Private hospital	3	6
	Village doctor	8	16
	Kobiraj	11	22
	Local pharmacy	23	46
Disease that was the reason to visit the doctor	Diarrhoea	14	28
	Skin disease	6	12
	Vomiting	11	22
	Fever	9	18
	Dizziness and headache	4	8
	Musculoskeletal complaints	2	4
	Others	4	8

Table 5. Occupational health safety strategies by the small-scale fisheries at the lower Meghna River, Bangladesh (n = 50)

Strategies	Frequency (n)	Percentage (%)
Sought treatment	21	42
Applied local indigenous knowledge	32	64
Storage of medicine	16	32
First aid box	14	28
Floating materials	34	68
Mobile	38	76
Dependent to other on all above issues	5	10

OCCUPATIONAL CHARACTERISTICS

Seasonality in fishing access tends to be a factor in livelihood diversification [5]. Most of the fishermen (84%) fish more than two times per month in a single season, whereas Mandal et al. (2017) [29] found that 77.5% fish two times in a single fishing year. Thirty two per cent of fishermen had 10 to 20 years of fishing experience, which was similar to the findings of Zytoon (2012) [30]. The study revealed that 72% of small-scale fishermen fish in the deep-sea year-round, except for during the banning period. The amount of time people spent fishing differed depending on location and season [5]. The present study also revealed that most of the fishermen (78%) were associated with small-scale fishing, which was supported by the findings of El-Saadawy et al. (2014) [13]. *Chandi jal* (34%) and *tempo or chandi boat* (40%) were used by the SSF fishers for catching fish in the present study, which was similar to the findings of Haque et al. (2017) [31].

OCCUPATIONAL HEALTH HAZARDS

About 72% and 60% SSF fishers suffered from diarrhoea and skin disease, which is higher than the findings of Mandal et al. (2017) [29] at Kachua Upazila and the Bagherhat district and Laraqui et al. (2018) [32] at Morocco. This is mainly caused by the incognizance of fishermen. According to John et al. (2016) [33], people who work outdoors are more susceptible to an augmented skin cancer risk compared to those who work indoors. In addition, Burke et al. (2006) [34] revealed that the threat of skin and eye damage was exceptionally high due to the unobstructed reflection of the sunlight on the river. There are also many harmful types of bacteria in river water, which can cause skin rashes and itching.

During fishing, fishermen suffered from various occupational injuries. In this study, 78% of fishermen reported that they have experienced occupational accidents, whereas in Frantzeskou et al. (2012) [14] of Greek fisherman, 28% reported experienced accidents. Most of the hazards occurred due to their inability and less conscientious use of protective tools. Thirty-eight per cent of small-scale fishermen were exposed to sunburn during their long hours of river work, which was supported by the findings of Warthan et al. (2003) [35]. According to most respondents (78%), red-eye is a sig-

nificant issue while fishing within the considered area, which is caused basically by air stream and results in obscuration of distant objects. Due to this air stream, fishers' eyes become inflamed and discharge water. Another cause of the decreased visualising power of eyes was utilising saline water while fishing. As a result, fishermen's eyes became inflamed, and water was discharged.

The working environment is not relaxed, as fishers need to remain working during long trips on the vessel. Other factors that might reduce security in the workplace include isolated locations, days with little rest, exposure to cold, considerable physical exertion, equipment failure, constant financial pressure, and regular mental stress. All of these components may increase the chance of harmful symptoms in fishermen. Fishermen endure diverse physical and mental stresses [19]. Most of the fishermen suffered from dizziness (78%) and vomiting (72%) during fishing due to the swinging of the boat by waves, which was similar to the findings of Mandal et al. (2017) [29]. Due to irregular eating habits, 72% of fishermen faced stomach acidity problems while fishing. The present study also revealed that 68% of SSF fishers suffered from musculoskeletal disorders, which was less than the findings of Mandal et al. (2017) [29], El-Saadawy et al. (2014) [13] and Percin et al. (2012) [36]. Twenty-six per cent of the fishermen had auditory complaints due to long periods of being in close proximity to machines and vessel engines, whereas Mandal et al. (2017) [29] and Percin et al. (2012) [36] found 25% and 21% of fishermen reported such complaints, respectively.

HAZARDS DURING FISHING

The risks of hazards were high in the rainy season compared to those during winter and summer, which was supported by the study of Mandal et al. (2017) [29]. The highest number (66%) of fishermen said they had encountered extreme cyclonic events while fishing, whereas Mandal et al. (2017) [29] found that 56% of fishermen in the Boga community at Kachua, Bagerhat reported encountering such events.

BEHAVIOUR FOR SEEKING HEALTHCARE

In Bangladesh, healthcare providers have been visited by more people with strong education and economic backgrounds than by those who are poorly educated and have less-advantaged financial backgrounds [37]. According to the present study, most of the small-scale fishermen had a primary-level education, which made them less knowledgeable about their illnesses and visits to facilities for health services. The present study revealed that 68% of fishermen visited a doctor for their treatment, which was much higher than the findings of Al Noman et al. (2020) [38]. Ten per cent of fishermen preferred to visit the government hospital, which was similar to the findings of Al Noman et al. (2020) [38]. The highest proportion of fishermen liked to visit the local pharmacy (46%) and *Kobiraj* (22%) due to ease of access and lower cost. According to Anwar et al. (2020) [39], fishermen and their families confront a variety of health-awareness issues, many of which are likely to have major negative effects on their health.

OCCUPATIONAL HEALTH AND SAFETY

For the most part, fishermen are at risk for multiple infections because they remain in an isolated aquatic setting for long periods of time [40]. Fishing can be a particularly dangerous occupation, with a high probability of work-related and endemic infections [14]. Forty-two per cent of the respondents looked for any treatment by local medical providers who are known to them, offer services 24 hours a day, are trusted and willing to negotiate payment, and who facilitate the purchase of pharmaceuticals from their dispensaries. According to the present study, 64% of SSF fishermen used their indigenous knowledge to treat health problems (headache, reflux, and fever), which was similar to the findings of Mandal et al. (2017) [29]. According to Rafnsson (1998) [41], good boat design and construction, appropriate navigation and communication equipment, personal life-saving devices (flotation devices, life buoys, and rescue sailboats), and swimming capabilities are crucial to mitigate the potentially catastrophic effects of accidents and ensure survival.

CONCLUSIONS AND RECOMMENDATIONS

The SSF fishers on Bangladesh's rivers are mostly dependent on fishing for their livelihoods. They are exposed to many risks, including skin problems, fever, musculoskeletal complaints, and problems with the auditory system, which lead to many diseases. Moreover, it appears that most small-scale fishermen suffer from high stress and sunburn, and there remains the hazard of accidents and injuries. Other risk factors associated with these problems were found to be long working hours, in particular on small, insecure boats and with a lack of personal protective equipment. In the rainy season, each fishing team faces natural hazards, mainly tropical cyclones. They experience long-term effects after facing numerous natural hazards and suffer health problems that decrease their work productivity after a certain age. They bring few medications or life-saving equipment for temporary health safety. Even the top fishermen have not received any training in their trade, which increases the risk of mortality while fishing. However, following few recommendations can be drawn based on our research findings and the existing context of small-scale fisheries sector in Bangladesh for the improvement of socio-economic status of fishermen:

— Increase access to education of children of fishermen;
— Provide better facilities for available pure drinking water, improve housing and electricity facilities;

— Government subsidies to fishers should be improved to help them get rid of *dadon* and on a soft-term basis, institutional loans should be offered to fishers;
— Arrangements for alternative income-generating activities for fishermen during lean and ban fishing periods should be created;
— Minimum or interest-free bank loan should be offered to support livelihood of SSF;

For the improvement of fishing practice following suggestions should be considered:

— Fishermen should use personal protective equipment (floating equipment, life jackets with reflective tapes or active lighting systems, lifeboats), and goggles to protect themselves from hazards;
— Good design and construction of boats, as well as adequate navigation and communication equipment, are essential to mitigate the potentially catastrophic effects of an accident;
— Fishers must be aware of and strictly follow the weather forcast to avoid accidents associated with natural calamities.

To improvement of physical/health safety of fishermen following recommendations should be ensured:

— To provide medical and health care services, health and safety guidelines must be formulated, focusing on issues such as expanding health insurance coverage and building up occupational health and safety units in major fishing ports;
— The government should provide training on how to improve safety and health by detecting hazards, assessing risks, and taking action to mitigate them through safety management and regular consultations on safety and health issues should be ensured by the government;
— Availability of first-aid kit boxes and primary medicine for the immediate health care of fishermen.

Additionally, some time demanding following options are recommended as guidance for the government agencies:

— The government should develop standard guidelines for safe (e.g. safety at sea for small-scale fisheries in developing countries) and responsible (e.g. code of conduct for responsible fisheries) fishing and safety (e.g. best practices to improve safety at sea in the fisheries sector) of fishermen must be maintained by increasing the number of coast guards and police officers on patrol;
— Secure the license of fishermen and fishing vessels, and enforcement of fishing rules according to Marine Fisheries Ordinance, 2020 to avoid illegal, unreported and unregulated fishing.
— Make sure monitoring control and surveillance system for the safety of SSF;
— Governments should encourage to engage in awareness development and capacity building activities such as courses, workshops and training on occupational safety and hazards, and awareness should be raised through seminars, posters, banners, television programmes, radio programmes, social media etc.

Conflict of interest: None declared

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Effects of global pandemics on hygiene-based contactless logistics in COVID-19 process and the eighth right of logistics: "right hygiene"

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ABSTRACT

This study aims to realise hygienic contactless logistic activities to ensure more secure sustainability of logistic movements, in order to protect global logistics from pandemics such as coronavirus disease 2019 (COVID-19) which was first seen in Wuhan, China in the first quarter of 2020. The Industry 4.0 and hygienic contactless logistics has been examined and defined for hygiene-based contactless logistics, a concept that is considered new in logistics literature. During the COVID-19 pandemic, contactless logistics and the eighth right of logistics called "right hygiene" practices will reduce the risk of human-induced diseases and support the sustainability of logistics activities with physical distance between machine and human as the concept of social distance. In the study, the terms of hygiene-based contactless logistics has been introduced into the literature and in addition to the accepted '7 Right Principles of Logistics', an eighth right one called "right hygiene" has been proposed.

(Int Marit Health 2022; 73, 1: 20–31)

Key words: contactless logistics, COVID-19, pandemic, Industry 4.0, right hygiene

INTRODUCTION

Since the beginning of the world, unexpected events have always occurred on a global and regional scale. An example of these events is the coronavirus disease 2019 (COVID-19) pandemic, which has recently become the centre of attention and has affected the whole world. Revealing their effects on transportation sector as well as in other sectors, the measures taken due to the coronavirus caused significant contractions. All kinds of economic activities based on contact between people came to a halt, causing serious disruptions in the global supply chain. Since the COVID-19 pandemic has deeply shaken the future of the transportation and logistics industry, the sustainability of economic activities by prioritising human health depends on the survival of the logistics sector.

The logistics sector is one of the sectors that experience the negative effects of epidemics first. Triggering the disruption of the global logistics system, epidemics have become a serious threat to the logistics industry. Hygiene-based contactless logistics has a very strategic importance for meeting social needs and ensuring the sustainability of the supply chain during global epidemics.

In the study, by mentioning the basic understanding of Industry 4.0, the lack of a defence mechanism for pandemic periods has been pointed out and some suggestions have been made. It has been emphasized that the logistics sector, which has a very fragile and sensitive structure, has applications for contactless logistics at the core of Industry 4.0 against possible pandemics in the fictionalised Industry 4.0, but these applications are not aimed at the concept of hygiene-based contactless logistics resulting from pandemics.

HISTORICAL DEVELOPMENT OF PANDEMICS

Infectious diseases have been an integral part of human history. One of the most prominent features of pre-industrial

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societies is their extreme vulnerability to all kinds of natural disasters. War and famine were less direct causes of death than natural disasters and pandemics [1]. Famine and unhygienic living conditions caused by wars have almost every time led to pandemic diseases. As a result, many epidemic diseases such as smallpox, typhus, cholera, influenza, and plague have emerged throughout history and have deeply affected people's psychology and their demographic, social and economic life. These kinds of epidemic diseases have spread around the world through tradesmen and soldiers and have become a threat to humanity in all historical periods.

Plague has the worst reputation in history books. First seen in Egypt, plague spread to Palestine and the whole world. It hit port cities and coastal cities primarily through sea travel. Especially the cities on the Mediterranean coasts could not get rid of plague, which was constantly carried via sea transportation, and the ships that were thought to be plague-infected were tried to be kept away from the shore [2]. Each ship that was kept away caused significant disruptions to the supply chain of that time by obstructing the regular flow of logistics activities.

The pandemic continued worldwide for a very long time and spread dramatically both via trade routes and wars [3]. The pandemic greatly damaged logistics activities because of spreading rapidly from port to port via sea transport and affecting the whole world in a period of ten years [4].

Cholera originating from India caused significant losses in many parts of the world in the 19th century [5]. Especially, the cholera seen in Istanbul is likely to have been transmitted from the Albanian people or from the ports and piers in Garbi Thrace where the soldiers stopped on the way [6].

Although the military personnel were considered to be the victims of the disease during the 1918 Spanish flu pandemic, the disease spread rapidly to the civilian population in America. The war paved the way for the globalisation of this virus [7].

Another type of influenza, known as the Asian flu, occurred in East Asia in February 1957 and caused 1.1 million deaths worldwide by triggering a massive pandemic [8].

Severe acute respiratory syndrome (SARS) first appeared in Guangdong province of China in 2002, and the disease, defined as a global danger, killed 774 people worldwide in March 2003 [9].

Known as swine flu, swine-origin H1N1, a new type of influenza, was first seen in Mexico in 2009 and this pandemic resulted in high mortality rates in a short time [10].

Middle East respiratory syndrome-coronavirus (MERS-CoV), which was detected in camels in the Arabian Peninsula, has become a danger for all humanity due to its potential to become an epidemic [11].

Undoubtedly, every large-scale epidemic in the world has deeply affected the global trade and logistics sector of the time. While we previously struggled with infectious diseases such as plague, Spanish flu, AIDS, Ebola, and SARS, now we are facing COVID-19 [12].

As a result of the emergence of coronavirus disease in Wuhan, Hubei province of China in 2019, the pneumonia, which attracted great attention not only in China but also in the international arena, turned into a pandemic in a short time and became a threat to the world economy and supply chain. With the slowdown of the Chinese economy, the flow of global supply chains has been disrupted. Contractions have been observed in companies around the world. As transportation became very limited among countries, global economic activities have slowed down, causing panic in consumers, and companies and disrupting the consumption patterns that we are used to and causing anomalies in the market [13]. This situation has led people to look for new ways out to prevent disruptions in existing logistics activities and supply chain.

THE RELATIONSHIP BETWEEN PANDEMICS AND LOGISTICS

Epidemics are a disaster that drains the human and economic resources of every state. Pandemics have caused serious drops in the human population throughout history, leading to an important loss of production and demand during epidemics. And lack of production and demand directly causes contractions in logistics movements. Therefore, the relationship between the epidemics in history and the logistics requires to be examined directly through population and trade.

The plague epidemic that emerged in the 14th century in Central Asia was transmitted to the world through trade [14]. The disease spread by land and sea severely in some regions and slowly in others. The population of the regions and the proximity of the ports and trade routes to the city greatly influenced the severity of the spreading [15].

It cannot be considered that the epidemic affected only the population negatively. The population decline due to the epidemic also negatively affected the logistics activities, having an indirect impact on the economy of that period, and caused economic difficulties.

Periodic losses in the population after the epidemic have led to an increase in the life quality of the survivors in the long term. However, in the short term, it caused a decrease in demand in the economy and caused the logistics movements to contract.

One of the common aspects of all the epidemic diseases is that they spread rapidly through the logistics activities, initially on a regional scale and then on a global scale, and affect the world trade and the logistics transportation, which is the conductor of this trade, in a negative way.

It can be easily deduced that in the historical process epidemic diseases have negatively affected the world trade

and indirectly the logistics sector in the short term. However, a different implication may be considered for the long term. According to the conditions of that time, the plague, which had the highest mortality rate among the mentioned epidemics, Spanish flu and other epidemic diseases, would lead to the death of millions of people, and when considered in the long term, this would cause a massive population loss and consequently a decrease in birth rates, and a decrease in the actively working young population. This logically increases the price of the labour factor. The increase in the price of the labour factor increases the income of individuals. The increase in the income of individuals directly increases the demand for manufactured goods. Long and short distance transportation of goods will increase and so will logistics activities in the long term in order for the goods produced in larger quantities to reach the final consumer as a result of the increase in production due to demand. Epidemics in world history have undeniably deeply affected the logistics sector through world trade and will continue to affect it in the future. In this context, more secure sustainability of the logistics movements of world trade without endangering human health will undoubtedly be very important.

THE CONCEPT OF HYGIENE-BASED CONTACTLESS LOGISTICS

We know that the perceptions of the logistics industry in the market are very fragile and sensitive in the face of sudden epidemics. The International Monetary Fund's claim that the impact of COVID-19 on the world economy may be worse than the Great Depression of 1929 [16] can be interpreted as a sign that the current global pandemic will deeply affect the world economy and undoubtedly the logistics industry in the short term.

A road map and a depth strategy of the logistics sector should definitely be created in possible large pandemics before major fractions turn into earthquakes. The logistics infrastructures of the future production and consumption facilities must be planned and a communication process that is absolutely coordinated with the logistics system must be started. The "hygiene-based contactless logistics" system, which will be one of those opening doors of the future in the logistics sector, must definitely be established and developed.

THE CONCEPT OF HYGIENE-BASED CONTACTLESS LOGISTICS

Logistics contains the purchase of raw materials, the production of goods and their delivery to consumers, and the withdrawal of the products because of reasons such as recycling and spoilage. The concept of hygiene-based contactless logistics is a systematic and sustainable fulfilment process of all the stages above, which are included in all the supply chain stages, with a contactless transportation network system in order to supply the demanded products directly or indirectly. In fact, the concept of "social distance", which emerged with the COVID-19 pandemic and has become a very popular slogan today, is the hygiene caused by the distance range put by human to human, in other words, the hygiene caused by the contactlessness based on the distance between the "machines and people" actively working in the production and logistics process in industries. The basic philosophy of the hygiene-based contactless logistics process in which there is no or minimized human intervention is that the less contact means the more hygiene.

For today's people, it is an undesirable situation for them not to be able to meet their most basic needs due to the lack of health services, the disruption of production activities and the broken supply chain. The political power in each country should concentrate on emergency action plans to keep production activities and supply chain uninterrupted due to the epidemic. This is because the cessation of production and supply chain will directly hit the economy and consequently the logistics sector. There is no logistics in a place where there are no production activities. In this case, it can be stated that the logistics sector, which is in communication with different sectors, is directly affected by the current epidemic.

Although the virus seems to concern health sciences more, it is actually the tip of the iceberg. Its effects on sociology, economy and logistics, in other words, its effects in socio-ecological aspects, will be deeper in the invisible parts of the iceberg. In this respect, in order not to digress from the main subject, the subject will be expanded by focusing on hygiene-based contactless logistics only through the logistics dimension.

THE PROCESS OF HYGIENE-BASED CONTACTLESS LOGISTICS

The process of hygiene-based contactless logistics, unlike that of the traditional logistics, is a logistics process that aims to eliminate human contact during the process from the starting point of the raw material to its delivery to the final consumer and from them to the producer again.

In the COVID-19 pandemic, workers in transport sector rank first among those who are potentially at risk. To illustrate the connection between hygiene and all kinds of action chains in which human beings are actively involved such as cargo delivery workers, motorcycle couriers, maritime/airline/railway and harbour workers, it can be stated that the human factor being at the maximum level during epidemics that endanger human health will increase the contact, which will cause a decrease in the hygiene level. In this case, it would not be wrong to suggest that there is a negative interaction between human and hygiene.

In short, the primary goal of the hygiene-based logistics process is to add the hygiene factor to the logistics process in order to ensure the protection of human health by eliminating any kind of human-based contact via the contactless production, packaging, loading-unloading, transportation, warehousing, delivery and paperlessness, and to ensure that the logistics processes are carried out without contact.

THE PROCESS OF CONTACTLESS PRODUCTION

Production is the name given to all activities made to produce goods and services that will meet the needs directly or indirectly [17]. In the process of the hygiene-based contactless logistics, the contactless production process supports the elimination of the human factor and ensures production through intelligent robots with artificial intelligence, whose use will increase day by day with Industry 4.0.

THE PROCESS OF CONTACTLESS PACKAGING

Packaging of the manufactured products is a very important stage in terms of hygiene. At this stage, minimising the human factor and even eliminating that factor in this process will increase hygiene.

THE PROCESS OF CONTACTLESS LOADING-UNLOADING

Loading can be defined as transferring the raw material or the manufactured product to the transport vehicle or into a container with the necessary equipment; and unloading is, as the opposite of loading, to take the loaded products out of the transport vehicle or the container which contains the products. Loading and unloading operations are included in the entire logistics process. For example, the simplest example of this situation is that after the raw material is loaded on the vehicle, sent to the manufacturer and unloaded from the vehicle, the manufacturer also reloads the product he produces in the same way to deliver it to the final consumer and the buyer performs the unloading. The presence of human factor during the loading-unloading stage poses a serious threat in terms of hygiene.

THE PROCESS OF CONTACTLESS TRANSPORTATION

Transportation is defined as the delivery of a good from the place where it is produced to the desired place as required and as making a planned, efficient, fast and safe transportation [18]. The point to be noted here is safe transportation. Safe transportation actually ignores the hygiene factor while involving safe, undamaged and efficient transportation of products. However, unhygienic transportation will seriously affect human health and destroy the trust factor.

THE PROCESS OF CONTACTLESS WAREHOUSING

Warehousing is briefly a logistics activity that aims to stockpile the products transported between the producer and the consumer [19] and to deliver the stocked products on time to the relevant place as quickly as possible [20]. Although human contact is less than other activities in this process, it is still an activity that needs attention.

THE PROCESS OF CONTACTLESS DELIVERY

The purpose of a logistics process is to produce the requested product and deliver it to the end user. As in other stages, the main goal is to eliminate contact between human and product. Today, there are some studies on "Contactless delivery and Contactless shipping". For example, while some cargo companies have minimised the contact factor by switching to the delivery system with the SMS code, some cargo companies are working on drone delivery to completely eliminate contact.

PAPERLESSNESS

Today, with the development of technology, there have been changes in all areas of trade. Of course, the technology used in logistics has also adapted to this situation, and all documents used in trade and transportation have been transferred to the electronic environment. In the pandemic environment we are facing today, considering that the sector employees avoid contact as much as possible, it will be healthier to process the paperwork in electronic environment based on hygiene-based contactlessness.

THE RELATIONSHIP BETWEEN CONTACTLESS LOGISTICS AND INDUSTRY 4.0

The fourth stage of the industrial revolution is characterised by the introduction of "cyber-physics systems" in factory processes. We are in a period when these systems will be combined in a single network, be in a real-time communication with each other, configure themselves and learn new behaviours. Such networks will be able to produce accurately with fewer errors, interact with manufactured goods and, if necessary, adapt to new consumer needs [21].

These products are distinguished by sensors that provide feedback to the production system, identifiable components and processors that carry information to convey effective guidance to customers [22]. Industry 4.0 presents the logistics systems that the whole world needs, especially in today's conditions. New production and information technologies aim to draw humans away from human-oriented production and logistics activities to a large extent, just as we wish, although not completely for now. It creates a competition by taking the labour power, which is among the large population of the east, from the countries providing cheap labour, while minimizing the use of labour, which is

one of the factors of production in the economic sense. While this competition was achieved, they were not aware that they were preparing for an unexpected epidemic in the 4th industrial revolution. It is obvious that it is vital to minimize the use rate of the labour factor both in production and logistics in order to prevent the spread of COVID-19, which is an epidemic that is sweeping the world today, and similar epidemics. Companies that implement hygiene-based contactless logistics in the period of Industry 4.0 will gain a significant competitive advantage. Firms that fall behind this competition will have difficulties to survive as they will lose their competitive advantage in the future.

In this period, when people are struggling with a rapidly spreading epidemic on a global scale, the necessity of the transport systems that can make autonomous decisions, the digital supply chain and the hygiene-based contactless logistics is obvious. It can be easily predicted that the process of hygiene-based contactless logistics, where human intervention is minimized, will prevent the spread of epidemics. However, it should never be forgotten that the human factor planned in Industry 4.0 should never be completely eliminated in the processes of hygiene-based contactless logistics and production. In the third industrial revolution, man was a mere means of production such as machinery, raw materials and capital. With the digital or fourth industrial revolution, the labour factor is in the process of being gradually removed from the production and supply chain. Although there is no problem in terms of transition to a more prosperous world order by providing the needs of a rapidly increasing world population in a faster and contactless environment, if we evaluate the situation with a Malthusian (Thomas Malthus) approach in terms of historical process with reference to the idea that human population increases geometrically and goods and services increase arithmetically, industrial revolutions have always emerged as a search for a solution. In other industrial revolutions, the human factor was never removed from the production and supply chain. However, with Industry 4.0, which we call the fourth industrial revolution, the labour factor is gradually removed from the production and supply chain, but a solution for where and how people will be employed in the increasing world population has not been offered. Moreover, it should never be forgotten that the world population, who was left unemployed with the exclusion of people from the production and supply chain, consists of those who demand goods and services that are produced and distributed without people.

A formation without those who demand will bring about social anarchy in the long run. No matter how much we provide the most perfect, most flawless, and healthiest goods and services, an unmanned world economy is unthinkable. Man is not an unidentified means of production. Let the people live so that the economies live, and the civilizations live. With Industry 4.0, people are trying to create heaven in this world, but what should not be forgotten is that paradise without people becomes meaningless.

The service types demanded from logistics, which is one of the leading sectors affected by Industry 4.0, are also diversified with the digitalization of industrial processes [23]. Especially with the rapidly developing technology revolution in the last century, the life of the products has been shortened. The advancing information technology has introduced the digital information economy. The shortening product life curves on a global scale caused the production to be transportable all over the world. This complex production system required new logistics and supply activities [24].

Logistics enterprises have to use high technology to continue their activities and compete during epidemics. The logistics sector has started to use many technological developments such as unmanned aerial vehicles, smart robots, autonomous vehicles, cloud computing, three-dimensional printing, face and voice recognition technologies, bionic robots, and big data analytics [25]. All the political authorities seeking the best in production, trade, politics, health and logistics around the world are paying a heavy price to get out of this difficult process that we are going through [22].

Changes in global trade are mainly due to economic, technological, political and natural factors. In economy, countries can increase or decrease their footprint through goods and service analysers or import markets. Technological innovations can increase the country's footprint and improve the cost and effectiveness of global trade. In addition, the ideology adopted by governments has influenced trade-related policies, shifting from more open to more protective trade policies. Recently, firms are challenging another type of global change that has the threat of spreading the coronavirus called COVID-19 [26]. Cargo companies, in particular, continue to deliver the manufactured products to consumers. In a sense, companies that understood and developed Industry 4.0 survived in the face of a sudden epidemic. We are experiencing a process in which logistics companies must be ready to serve within the framework of the necessity of Industry 4.0. With Industry 4.0, industrial organizations use natural resources more efficiently and reduce the damage they cause to nature. New ideas and inventions are implemented quickly at much lower costs. However, we believe that the logistics sector, which is very fragile and sensitive in the face of epidemics, does not intend to create a conscious defence mechanism against epidemic diseases in Industry 4.0, although it is planned that production and productivity will be directly proportional to the idea implemented, not to muscle power.

Although the basic understanding of Industry 4.0 is to increase the quality of life of people based on high tech-

nology and innovation and to increase productivity with low costs by providing superiority against competitors with the latest technologies, an important factor that will be a serious threat for itself has unfortunately been overlooked. Indeed, Industry 4.0 indirectly supports the concept of hygiene-based contactless logistics, since it essentially means reducing the use of the labour factor within the industry. The concept of contactless here is closely related to human health.

Thanks to the developing technology and artificial intelligence, a product that weighs tons is placed on a ship, train, container without human touch, and the location of the vehicles traveling with the transport mode can be traced and monitored with mobile applications. The threats created by such pandemic diseases will be prevented by eliminating the human factor as a result of the widespread use of unmanned trains and aircraft after self-moving trucks in China. Hygiene-based contactlessness will increase in parallel with the dominance of machinery and devices in logistics. These unmanned vehicles will reduce the risk of human-caused epidemics and ensure the sustainability of logistics activities. COVID-19 has proven to the world that the efforts for contactless logistics can be vital.

It should not be forgotten that we do not think that contactlessness alone and hygiene created accordingly by removing the human factor partially or completely from the contactless logistics process can save people from epidemic threats. However, we are of the opinion that it is the most important actor in terms of solving the problem, although it is not a solution alone. In fact, with Industry 4.0, there is an increase in the need for the human brain, but a decrease in the need for manpower.

INTERNET OF THINGS

Internet of Things is one of the most popular technologies of today and one of the technologies that companies prefer to invest the most. The Internet of Things enables a safe, measurable and traceable management with opportunities such as real-time tracking of the entire supply chain, barcoding, and the use of vehicle and fleet technologies in the logistics sector [27]. In short, thanks to the Internet of Things named "The IoT", the products will be prevented from falling in freight transportation, and sensors and cameras will be able to detect risks and defective storage and calculate the falling probability of any product. Smart walkways, smart containers, smart warehouse management system, mobile localizations, and robots will change all the qualities of both the job and the people doing this job.

In addition to these, the innovations brought by the Internet of Things will enable the monitoring and visualisation of various wireless sensor applications in production areas such as automatic work cells, transportation systems, logistics and storage systems [23]. The Internet of Things has revolutionized the logistics industry. The fact that smart devices communicate with each other and act in accordance with the information they receive directly eliminates the intervention of the human factor. We can easily talk about a hygiene-based contactlessness in a system that is unmanned and indirectly that does not involve human intervention.

INTELLIGENT ROBOTS

The use of intelligent robots in the logistics sector will be an important development that provides the sector with advantage. In this way, physical contact between human and product will be eliminated.

Equipping robots with superior artificial intelligence and making them intelligent and their exhibiting autonomous behaviours will improve operations in the logistics process. Innovations in robot technology are expected to be a highly preferred investment in the upcoming years. Order picking is a challenging phase of logistics operations [28]. The operator collects the products by visiting the shelves where the orders are located, and in order to carry out this process in independent aisles, this not only causes waste of time but also creates a hygiene risk in the products as a result of direct contact with the products. It is possible to overcome this risky situation with robot technology.

The most characteristic feature of Industry 4.0 is making production thanks to smart robots in the sector. As robot technology advances in the world, the cost of robots decreases. With smart robots, technological tools and equipment are produced faster, and the need for human labour is reduced. Although robots are thought to reduce the need for human labour, they will increase the demand for skilled labour in matters such as technical support and software updates for robots.

As the interaction of intelligent robots with each other and their technology increase, the intelligent supply chain will develop with the use of robots at every stage of the supply chain, contactless transportation, storage, assembly and distribution processes will be provided thanks to transport robots moving on a track, and customer satisfaction will increase with a hygienic environment.

INTELLIGENT FACTORIES

Factories that can easily and smoothly manage highly complex production processes, whose products have a longer lifespan, and where production is made with autonomous robots using the latest technology, are called intelligent factories. With the Industry 4.0 revolution, the first foundations of intelligent factories were laid.

In intelligent factories, people, autonomous robots, machines that can communicate with each other and all other

production factors are in a deep interaction. Within the framework of cyber security, machines that are in communication with each other automatically stop the production when they encounter any problems and seek solutions to fix the problem. In intelligent factories, the realization of just-in-time production with the lean production method becomes a reality with the machines' planning the production resources [29].

The German Research Centre for Artificial Intelligence (DFKI) has developed a prototype called the intelligent factory with various manufacturers. The main feature of this factory is the integration of independent production modules that communicate autonomously with each other thanks to various information systems. People only play a supporting role in the production phase. The improvements are based on three main elements, which are the intelligent communication product, networked systems and assistant operator of the system [30].

With the increase in the number of intelligent factories and advanced automation technology systems, it is predicted that the need for unskilled workforce will decrease [31]. Thanks to the use of machines, robots, unmanned production lines, data and simulation techniques that are in communication with each other, productivity, speed, flexibility and quality will increase in production [29]. Mr. Warren G. Bennis says: "The factory of the future will have only two employees, a man and a dog. The man will be there to feed the dog. The dog will be there to keep the man from touching the equipment." [32]. And this statement wittily heralds that there will be no human beings in the intelligent factories of the future, and production and logistics activities will be carried out in a contactless manner, therefore based on hygiene.

THE RELATIONSHIP BETWEEN CONTACTLESS LOGISTICS AND INTELLIGENT PACKAGING

Packaging used in the production of basic food and necessity goods is important in terms of hygiene, as well as eliminating contact in a sense and it will ensure that all kinds of logistics movements of these products are made in a safer and healthier way. In this sense, packaging is of great importance in terms of hygiene-based contactless logistics. Incorrect packaging already causes the growth of bacteria, viruses, fungi and most of all, waste. Antimicrobial packaging, also known as active packaging, is one of the newest techniques in the protection of products that are highly susceptible to microbiological deterioration due to their chemistry. Antimicrobial packaging is a longer and more hygienic preservation of the product by providing a controlled release of the antimicrobial agent that is included in the packaging material and atmosphere [33].

The determination of the use of correct and environmentally friendly recyclable packaging in accordance with the laws and regulations will make the process of contactless logistics more effective and active.

CONTACTLESS LOGISTICS AND THE EIGHTH RIGHT OF LOGISTICS

The purpose of the services provided in logistics is to supply the product needed by the end consumer and to meet the seven generally accepted expectations of logistics in this supply process. This is called "7 Rights of Logistics". The 7 Rights of Logistics (the 7R rule) are fundamental to every logistics system without exception. The purpose of logistics is generally reflected in 7 rules and if these rules are followed, it is accepted that the logistics activity achieves its purpose [34].

1. Right product — First, the kinds of products to be handled and transported must be known. Having the right information will provide the advantage of managing both time and resources in an appropriate and efficient way.
2. Right place — A systematic distribution system and tracking is essential. Also, both the customer and the service provider must have synchronized location tracking to ensure that products are delivered to the right place.
3. Right price — An appropriate price value is essential to keep track of the company's income and expenses.
4. Right customer — The company must define its target market and choose the right customers.
5. Right condition — Any product or item to be entrusted to customers must be stored and delivered in right conditions. This is where specifications should be referred to place the quality where it can be maintained.
6. Right time — Every service provider must know the right time to deliver products and use it efficiently.
7. Right quantity — Knowing and determining the right quantity is essential for the most efficient transportation.

The 7R rule should be applied to all logistics processes available in the services industry, from raw material ordering and procurement, deciding on the right supplier, procurement management and shipping, and to sales and customer services [34].

Just as the effects of Industry 4.0 on logistics have reshaped what we know, it has revealed a reality that should have been noticed much earlier in the COVID-19 process. "Right hygiene", which should be the eighth right of logistics in our opinion, has now become a necessity with the opportunities provided by Industry 4.0 and the COVID-19 pandemic.

Seven basic principles apply in logistics. However, "right hygiene", a 'right' that is unlooked-for or not considered till the COVID-19 pandemic, should be added to these rights, and the eighth right should be taken as reference in en-

suring customer satisfaction. This is because, in the eyes of the customer, the COVID-19 pandemic has shown that no matter how right the first 7 rights are, if the 8th right, which is right hygiene, and the products provided from the supply network based on the right hygiene cannot be offered to the customer who is the final consumer and if this perception cannot be achieved on the customer, the other rights become meaningless. Failure to comply with the right hygiene rule during the pandemic process has led to the loss of customers, the disruption of the production cycle and, accordingly, to poor market positions.

The global epidemic of COVID-19 confirms our thesis, and together with the awareness of the world, no matter how right the "right price" application is, which is one of the seven rules of logistics, the point which the customer emphasizes along with the epidemic process is the product hygiene. And in this sense, the right hygiene rule has been observed to be way ahead of the "right price". Industry 4.0 has a direct impact on all the 7 rights of logistics and the "right hygiene" that we propose as the 8th right.

With Industry 4.0, investments to be made for information and communication systems and intelligent warehouse attempts, and other infrastructure needs within the framework of logistics 4.0 should be reconsidered by companies that we can call the pioneers of the sector in the context of contactless logistics and right hygiene, which we define as the eighth right. In addition, developments regarding the adaptation of intelligent systems to the contactless logistics sector should be scrutinised. All developments in the information sector and technology in the world must be integrated with the hygiene-based contactless logistics system in order to supply the product needed by the end consumer, which is the purpose of the services provided in logistics, and to meet the eight rights (8R) expectations in this procurement process.

Every global epidemic on a large scale can be overcome with a global struggle. The hygiene-based contactless logistics and the eighth right of logistics will be one of the most important weapons in this global struggle. In his idea of "creative destruction" [35], characterises this concept as the elimination and replacement of the old one by a new development and innovation emerging in capitalism. It's the best theory to explain the economic and social change. In the context of creative destruction, when a strong new structure or innovation emerges, old structures will completely lose their influence, and new structures and institutions will shape the new era [36]. In this sense, this is the truth that is intended to be expressed in the message within the slogan "nothing will be the same". "Contactless logistics" and "right hygiene", which we refer to as the eighth right of logistics, can be evaluated as an opportunity, a change, a renewal for the logistics sector during the COVID-19 pandemic.

HYGIENE-BASED, CONTACTLESS NEW GENERATION LOGISTICS

Along with unmanned ship transportation, driverless cars, tube and drone logistics, the logistics sector is experiencing an era of unmanned vehicles. While the logistics sector is moving towards taking advantage of these and similar advantages, and increasing productivity by reducing human-induced errors by adapting to this change and development in technology, it also aims to prevent all kinds of disease threats that can be transmitted by human contact with the emerging new generation transportation vehicles.

With the developing technology, transportation vehicles which will be the prominent vehicles of the future such as autonomous vehicles, ships without captains, pilotless planes, driverless trucks, etc. will gain a large place in the contactless logistics process, and deliveries with drones and transport with cargo robots will be actively carried out. As shown by the epidemic diseases experienced in the past and today, human-to-human and fomite contact increases the risk of epidemics and emerges as a factor that seriously affects human health. In this case, in the process of reducing anti-epidemic measures and getting used to the new normal order, it will undoubtedly be everyone's priority to provide the products that people demand with hygiene-based contactless logistics.

UNMANNED VEHICLES

Starting with unmanned aerial vehicles and extending to unmanned cars, and now getting to work on unmanned ships in the maritime sector [37], technologies aim to eliminate the human factor in transportation. And the logistics industry has begun to experience the era of unmanned vehicles with these technologies [38].

Shipping companies are speeding up their operations on unmanned ships to minimize human errors and reduce costs. The last example of this was Japan-based Nippon Yusen company [39]. Unmanned marine vehicles have many benefits to ship owners, and maritime industry, and in terms of environmental pollution and safety. More energy-efficient use of unmanned ships, easy and reliable operation, and reduction of accidents caused by human error are just a few of these benefits. Additionally, reduction in operating costs and emission use can be given as an example [40].

Autonomous vehicles without drivers are smart vehicles that can analyse in-vehicle information and information from their environment simultaneously using advanced systems, are equipped with independent decision-making capabilities, and can move on land. Self-driving vehicles play an important role in protecting human life by making fewer mistakes. In addition, self-driving vehicles will consume less fuel and cause less damage to the environment with smart driving methods [41].

What is emphasized among the main benefits of every unmanned vehicle is to reduce human-induced errors and environmental damage, and protect human health. What is mentioned here about protecting human health is the loss of life as a result of accidents caused by humans. However, one point has gone unnoticed. People do not only die from accidents. In the epidemic process, the example of which we see very clearly today, the human factor can put their lives and lives of others on the line through contact. For this reason, unmanned transportation vehicles will have an important place in eliminating the human factor in the contactless logistics process.

TUBE LOGISTICS

Traditional means of transport are expensive, slow and environmentally harmful. Traditional transportation vehicles will not seem very advantageous in the future due to the reasons like the damage of carbon emissions, fluctuations in oil prices, speed problems, and traffic congestion [42]. Tube freight transport is an unmanned transport system in which capsules or capsule trains carry freight with tubes between terminals. The system can be thought of as an unmanned train carrying containers in a pipe. High volume loads can be transported by tube freight transportation. With this transportation system, improvement in efficiency, lower freight rates and reduced environmental damage will be observed [43].

Tube logistics has many attractive features for future use. Since these systems are unmanned and fully automatic, they are safer than truck or railway systems. Because they are closed, they are not affected by the weather and are not subject to the most common rail or road accidents [42]. In addition to the mentioned advantages [25], the most important reason for the proposal to use tube logistics in the hygiene-based contactless logistics process is that the transportation is carried out unmanned and without contact. Tube logistics, which eliminates the human factor, will increase the hygiene factor to the maximum level by directly eliminating the contact factor, thus eliminating situations that will put human health at risk, especially during pandemics.

DISINFECTION TUNNEL

The environmental factor is a factor that can be the cause of diseases, affect the course and outcome of diseases, and facilitate the rapid spread of epidemic diseases to people and their environment, as well as laying the groundwork for the formation of diseases [44].

Disinfection process is the destruction of microorganisms that are found on living or non-living materials and may put human life at risk [45].

At this point, by integrating the disinfection tunnel application, which is also applied today, into the logistics process and increasing its use, the hygiene-based contactless logistics process that we have brought to the literature will be supported and the damages of the environmental factor will be minimised.

The disinfection tunnel is a system that enables the delivery vehicles sent to a quarantined area to be sterilized by disinfection. The system is very important both for human health and for preventing the spread of pandemics [46]. The vehicle entering the tunnel gets hygienic in detail with disinfectant liquid that has been cut into small particles [47]. This method used today will prevent the spread of possible epidemic diseases by reducing the effects of human contact, and will have an essential place in the hygiene-based contactless logistics process addressed before.

CAROUSELS

As the automatic storage system, which is divided into two as horizontal and vertical, carousels has movable shelves and rows. In this storage system, loading and unloading operations are carried out by moving racks and rows, eliminating human contact. As carousels have the ability to load-unload automatically with the modular system that can work alone [48], they will reduce the direct contact to zero and reduce the risk of the spread of deadly epidemics, which are still present today, and safeguard human health.

SMART CONTAINER SYSTEM WITH DRYING OVEN

During the cholera epidemic in 1894, serious measures were taken and vital drying ovens started to be used [49]. In fact, the purchase of drying ovens increased and it was planned to make people's clothes sterile by circulating these machines in the neighbourhoods [50].

Drying ovens are a kind of laboratory oven, which are in different volumes, adjustable between 60 and 250 degrees, and airtight. They are used for heating, cooking, and drying in a certain temperature range, and what interests us is that they're also used for sterilising and producing and killing germs. These ovens are commonly used to kill germs and disinfect various materials [51]. Since these machines, which have been frequently used in historical epidemics, are effective in destroying microorganisms, they will be placed in containers in case of any human contact after loading, and will ensure the destruction of microorganisms such as viruses, bacteria, etc. which are present or likely to occur in containers during transport, thus it will prevent possible diseases from spreading.

DRONE LOGISTICS

Reflections of technological developments in the world have also caused significant changes in cargo transportation with drone and have become an important part of the logistics industry. A total of 47% of the world drone market

is classified as civilian drones, and 24% as commercial drones, and the rest include drones created for consumer purposes [52]. Although the use of commercial drones seems to dominate a quarter of the market for now, this rate will increase rapidly in the future with the increase in contactless logistics activities. Logistics is in the process of evolving from traditional transportation vehicles to new generation ones.

Cargo transportation with drones, which will possibly be the most effective of the new generation transportation vehicles, has important advantages such as having lower costs and a faster delivery time compared to other transportation vehicles. In addition, an unnoticed advantage is that it will shorten the procurement process in the COVID-19 pandemic and in the future epidemic situations, preventing the danger of passing the product from hand to hand too much, and minimizing the human factor in the transportation system, thus, it will serve the hygiene-based contactless logistics process.

We believe that drones will be the future of hygiene-based contactless logistics. The plans of customers who do shopping in Reykjavik, the capital of Iceland, to receive food and other products at their doors with drones which significantly shorten the delivery time have gradually started to be implemented in real life. An Icelandic online retailer, Aha, continues its drone delivery service, which started in 2017 with Flytrex, by expanding its service area. With 700 m range and 13 different routes within a year, it has access to almost half of the capital [53].

Many retail and logistics companies around the world are striving to realise this dream. Amazon, Alphabet, FedEx, Uber, and UPS are some of them [54]. Every step to be taken by these and similar companies worldwide to establish the urban drone delivery service will contribute greatly to the hygiene-based contactless logistics system.

CONCLUSIONS

If the developments during historical pandemics are analysed carefully, it can be observed that change and transformation in many areas take place very quickly. It should not be surprising that similar changes and interactions occur after the COVID-19 global pandemic.

Continuing the sustainability of economic activities by keeping human health at the forefront in our blue globe, where the Atlantic age is questioned and where the Asian age is on the agenda, and where great changes occur, depends on the survival of the logistics sector. The pandemic has become a serious threat to the logistics sector. In this sense, it has a very strategic importance in terms of meeting the needs and ensuring the sustainability of the supply chain.

Undoubtedly, hygiene-based contactless logistics will provide countries and companies with a very important competitive and superiority advantage in the future. Although the basic understanding of Industry 4.0 is to increase people's quality of life with high technology and innovation, to gain superiority against competitors with the latest technologies and to increase productivity with low costs, it has been determined in our study that an important factor that will seriously threaten itself is unfortunately overlooked. The notion that an unforeseen pandemic would prevent the previously determined objectives from being achieved was missed. In fact, the core of Industry 4.0 was to increase the competitiveness by reducing the use of the labour factor within the industry. However, during the pandemic process, it was seen that reducing the use of the labour factor feeds the concept of hygiene-based contactless logistics as it will increase the hygiene-based contactlessness indirectly and unknowingly. The contactlessness here is closely related to human health.

Serious changes of directions are expected in the global supply chain during and after the COVID-19 outbreak. The worldwide COVID-19 pandemic caused a serious issue of trust on consumers with the fear that the products produced in monocentric Asian countries, especially those based in China, are not hygienic enough. These and similar thoughts will trigger and change the direction of the global supply chain. The companies that want to shift the route of the first wave of goods demands that will come from Europe, Asia and Africa and even beyond the Atlantic to their own countries, have to first rebuild their logistics infrastructures which will respond to the post-epidemic demand explosion on the hygiene-based contactless logistics and the 7+1 rights of logistics (7+ right hygiene) in relation to Industry 4.0. We are of the opinion that this situation will have a historical meaning in terms of the sustainability of the future strategies of countries that have important geostrategic and geopolitical advantages. As the effects of Industry 4.0 on logistics have reshaped what we know, COVID-19 has actually revealed a reality that should have been noticed much earlier. The concept of "right hygiene", which we call the 8th right of logistics, should be evaluated together with the opportunities provided by industry 4.0. In the face of all these consequences, we think that the 7 rights of logistics are meaningless and incomplete without the rule of "right hygiene" that we call the "8R".

The crisis environment created by the epidemic has tested the preparations of logistics companies on a global scale and revealed the problems encountered in this area very clearly. Global targets determined for the illumination of vague points that are encountered and not seen in the sector are presented below as suggestions.

Global goals for the development of sustainable contactless logistics:

— An innovative and robust infrastructure should be built against epidemics by reviewing the entire infrastructure of the sector, and all innovations for hygiene-based con-

tactless logistics should be encouraged by transitioning to a sustainable logistics process covering every sector;
- National and international logistics regulations need to be updated to support hygiene-based contactless logistics activities and ensure their development;
- By increasing the capacity of the amount of cargo carried at a time in land, sea and air transportation and by ensuring that more cargoes are carried via fewer vehicles, it should be ensured that transportation costs and environmental pollution, and the risks of spreading contact-based pandemics should be reduced;
- In order to bring the competitiveness of the logistics sector to the international level, research and development activities should be supported especially for hygiene-based contactless logistics;
- On a macro basis, international companies, on a micro basis, national companies need to design hygiene-based contactless logistics networks effectively and determine strategic distribution locations;
- Courses for contactless logistics should be offered in relevant departments of universities and organizations should be developed for contactless logistics;
- Innovative processes should be followed consistently by creating cities and settlements that comply with the principles of contactless logistics;
- Large trade ports and existing logistics centres should be re-coordinated and re-designed according to the contactless logistics system;
- National and international transport corridors (ports and border gates) in active use should be updated with improvement works for hygiene-based contactless transport.

During the COVID-19 process, the world experienced the supply and demand shock at the same time and faced a different crisis that it has never experienced at this scale. In this sense, one of the points that should be considered is that hygiene-based contactless logistics should be evaluated in relation to both supply- and demand-side interactions. If the pandemic process is not managed well all over the world, global economic costs will have to be paid. Every global epidemic on a large scale can be overcome with a struggle on a global scale. Hygiene-based logistics and the 8th right of contactless logistics will be one of the most important weapons in this global struggle. Based on Schumpeter's idea of "creative destruction" (1942), "contactless logistics" and "right hygiene", which we define as the 8th right of logistics, can be considered as an opportunity during the COVID-19 pandemic process.

We believe that our study on hygiene-based contactless logistics will make considerable contributions to future research on this issue and to the research findings.

Conflict of interest: None declared

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Comprehensive analysis of yacht masters operating in Bodrum district in terms of fatigue, burnout, and job satisfaction

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ABSTRACT

Background: *Yacht tourism is a developing sector in the world and in Turkey as well. Yacht masters are the most important components of this sector. This study aims to investigate the factors affecting the fatigue, job satisfaction, and burnout levels of yacht masters, offer solutions according to the findings, and eliminate this deficiency in the literature.*

Materials and methods: *The Maslach Burnout Scale (MBI), Minnesota Job Satisfaction Scale (MSQ) and Piper Fatigue Scale (PFS) were applied to yacht masters who are still actively working on yachts operating in the Bodrum district. Data analysis was performed using Statistical Package for the Social Sciences (SPSS) software.*

Results and Conclusions: *According to the results of the analysis, yacht masters have high emotional burnout perceptions and very high personal success perceptions. In addition, their depersonalisation levels are low and their overall job satisfaction is high. The general fatigue levels of the masters are moderate. As their job satisfaction rate increases, their perceived fatigue level decreases. As their age increases, their fatigue level decreases. As their fatigue level increases, their burnout level also increases.*

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Key words: Maslach Burnout Scale (MBI), Minnesota Job Satisfaction Scale (MSQ), Piper Fatigue Scale (PFS), yacht tourism, maritime

INTRODUCTION

Yachts and yacht tourism are symbolic industries that represent modern seaside cities' development. Guests who prefer yacht tourism usually travel in small groups in close contact, are respectful of nature, and do not disturb local communities [1].

Yachting or yacht tourism is a specialised tourism activity that is limited to cruising activities on the water [2]. In addition to using boats as shelters, recreational facilities, and means of transportation, yacht tourism offers groups or individuals unique touristic experiences intertwined with the sea [3].

The yacht tourism sector, known as a service sector and includes sightseeing and entertainment, moves forward with yachts equipped with well-trained crews to meet the guest service demand of the marine tourism industry [4]. Yacht crew should provide elite service to their passengers, satisfy their gastronomic preferences, and provide entertainment and relaxation for passengers [5]. However, it should have the knowledge and skills to respond to emergencies such as fire and ship abandonment [6]. Yacht masters, who are the leaders of the yacht personnel, should check and monitor that all these tourism service activities and emergency

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training are carried out by the personnel, as well as the operational management of the yacht [7].

In the Mediterranean basin, which includes Turkey, the intensity of yacht tourism activities increases during the summer months [8]. It is defined as the high season between July and August in yachting [9]. Yacht crews are faced with difficulties such as working in extremely hot weather conditions, work stress and insomnia, inadequate physical conditions, and excessive workload, especially in this high season [10]. Due to the increasing touristic activity, the workload of yacht masters also increases significantly [11]. Heavy workload in the working environment is an important risk factor for burnout [12]. It is a well-known fact that a seafarer must work in a confined space away from home, in isolation from social life [13].

In theory, all onboard recreational activities for passengers can occur around the clock, and in practice, many sailors are on duty 24 hours a day. Many important environmental stress factors are added, such as psychosocial working conditions [14], vibration caused by the engine and noise inside the boat, temperature change caused by weather conditions and boat movements. Furthermore, long working hours, separation from family, fatigue, insomnia, work-related stress, risk of sea accident, multinational passengers, illnesses, and limited social activity make yacht personnel and masters vulnerable to burnout [15].

Developing technology, computer-controlled systems on boats have made boats technologically well equipped, but this advanced technology has led to a decrease in the number of workers on boats [16]. As a result, the workload of yacht personnel and yacht masters has increased.

According to the International Maritime Organization (IMO), fatigue is defined as a decrease in physical and/or mental ability resulting from physical, mental or emotional exertion that may impair performance [17]. Fatigue not only poses a threat to the individual health of seafarers but can also increase the risk of fatal accidents [18].

Freudenberger first described burnout in 1974. According to Freudenberger [19], burnout is the depletion of the employee's energy due to failures, overload, wear, loss of power and unmet expectations. The burnout inventory was developed by Maslach and Goldberg [20], who made the most important contributions to the literature on the concept of burnout. According to Maslach and Goldberg [20], burnout is handled in three dimensions. Emotional exhaustion, which refers to leaving one's job as a way of coping with the workload, is depersonalisation, which is the effort of the individual to distance himself from various aspects of their work, and a sense of personal accomplishment that expresses the inadequacy that develops due to the individual's lack of success and productivity at work [20].

Job satisfaction is a concept directly related to burnout. Job satisfaction is defined as the employees' perception of the job and their emotional reactions to this perception and the degree to which it meets their needs [21]. Job satisfaction is the satisfaction or dissatisfaction that employees feel towards their job. While the person with high job satisfaction has positive feelings about the job, the person with low satisfaction has negative feelings [22]. There is a linear relationship between job satisfaction and professional performance. As job satisfaction increases or decreases, the occupational performance also increases or decreases, respectively [23].

In the first part of the study, hypotheses were formed based on the research model and the demographic distributions of the participants were determined by frequency analysis. As a result of the Cronbach-Alpha values, the reliability analysis of the research was conducted. The normality research of the data used in the study was carried out with the Kolmogorov-Smirnov test. In the next section, descriptive statistics of the scales applied to the participants and the levels of their subscales are presented. A Pearson correlation analysis was conducted to determine the relationships between the participants' demographic characteristics, burnout, job satisfaction and fatigue of the participants and the levels of these relationships. Pearson correlation analyses were used to test the proposed research hypotheses.

This study is the first to evaluate the relationship between fatigue, job satisfaction and burnout levels among yacht masters. This study aimed to determine the factors affecting the fatigue, job satisfaction and burnout levels of yacht masters actively working on yachts by using the Statistical Package for the Social Sciences (SPSS) package programme.

MATERIALS AND METHODS

LITERATURE REVIEW

Due to the acceleration of all operational processes in maritime transport with technological innovations, the human factor has become a critical issue. Irregular and long working hours, rapid changes in working environments and other organizational and/or individual factors negatively affect seafarers' performance. Shipping involves various stressors that can cause seafarers to suffer from burnout. Job satisfaction is one of the most important factors affecting burnout. The yachting industry, the tourism-related branch of maritime, has different dynamics from commercial shipping. Yacht crew, including yacht masters, face challenges such as working in extremely hot or cold weather conditions, work stress and insomnia, poor physical conditions, and an excessive workload, particularly during high season. The resting times of yacht masters

depend on workload. In the high season, the workload of yacht masters increases significantly due to increased tourist activity.

Whether all these factors cause fatigue and burnout in yacht masters and their job satisfaction will be revealed in this study.

Andresen et al. (2007) [24] focused on pilots in seven European countries and analysed their job satisfaction levels. According to the results of their research, although their quality of life decreased due to health problems and unusual working hours, most of the pilots stated that they did not regret their career choices. They also presented the factors that would improve the working conditions of the pilots in their studies. Accordingly, the most critical parameters include changes in working hours, working conditions that minimize physical exertion, justice in terms of salaries, and flexibility in the remuneration system [24].

Allen et al. (2007) [25] highlighted that global concern about the extent of seafarers' fatigue is expected in the shipping industry. In their study, in which they presented an assessment of the extent to which fatigue can be prevented and managed, they determined that keeping the number of personnel onboard to a minimum provides an economic advantage for the employer, but the minimum number of personnel increases the level of fatigue per person. They argue that preventing fatigue and creating optimum working conditions can be achieved with appropriate training and guidance [25].

Allen et al. (2008) [26] noted that fatigue was noticeably less researched in the maritime field than in other sectors. Their literature review searched 11 databases to evaluate the latest developments in the area and distil the issues that most worry and challenge the maritime community. While diversity in the seafarer population has the potential to render estimates of global fatigue meaningless, evidence of misrecorded working hours illustrates how cultural and commercial pressures are shared universally [26].

In their published article, Li et al. (2014) [27] investigated the main factors contributing to job satisfaction among Chinese seafarers. The data they used in their study was collected through questionnaires. They used a structural equation modelling method to test and predict causal relationships using a combination of statistical data and qualitative causal assumptions. They concluded that promotion was the most important factor in job satisfaction, followed by salary, work environment and a sense of status [27].

Sliskovic and Penezic (2015) [15] aimed to determine the level and sources of job satisfaction and dissatisfaction in their study with 530 Croatian seafarers working in various positions on cargo ships. According to the results of the study, it was found that the participants were most satisfied with the salaries and the least satisfied with the work organization on the ship. They stated that the main sources of job satisfaction were financial stability, security and the ratio of working days to days off. On the other hand, they concluded that the sources of dissatisfaction were both leaving home and family, and the working and living conditions on board [15].

Toz et al. (2015) [28] evaluated the related risks of work-related burnout levels in their study with 42 yacht masters to investigate the burnout levels of Turkish yacht masters using the emotional exhaustion approach of the Maslach Burnout Inventory (MBI). They concluded that overall emotional exhaustion and depersonalisation were low in yacht masters [28].

According to Bal Besikci et al. (2016) [29], in their research which aimed to determine the fatigue levels and mental symptoms of seafarers resulting from working conditions on board by using subjective measurements, the Piper Fatigue Scale (PFS) was used to measure the level of fatigue and the Symptom Checklist 90-Revised (SCL-90) to determine the severity of mental symptoms, and the data were analysed. As a result of their study, they determined that seafarers showed high levels of fatigue and mental symptoms. They also found that an increase in seafarers' fatigue increased their perception of mental symptoms and vice versa. In addition, they concluded that working at night negatively affected the fatigue of seafarers and increased the risk of accidents [29].

Zhao et al. (2016) [30] stated that fatigue had adverse effects on seafarers and the general working population. In 2016, researchers conducted a survey-based study to examine seafarers' fatigue, learn about potential risk factors, and create indexes that show fatigue. Their research analysed work and sleep patterns in global shipping and compared European and Chinese seafarers on the basis of fatigue by applying the t-test. They concluded that the health and safety of seafarers were negatively affected by fatigue [30].

Kim and Jang (2016) [31] found that obsessive-compulsive behaviour, depression, and somatization were the most common symptoms among officers in their study of 160 officers in Korea, in which they aimed to investigate the relationships between job stress, job satisfaction, and mental health. They showed that the prevalence of psychoticism, somatisation, depression, anxiety and phobic anxiety was higher in officers who reported poor health, low job satisfaction and high job stress [31].

In their study, which aimed to test the relationship between different aspects of internet access onboard and the satisfaction and health of seafarers, Sliskovic and Penezic (2016) [32] surveyed a total of 298 Croatian seafarers with at least 2 years of work experience. According to the results of their studies, they noted that the time spent on board,

not exceeding the contract periods and internet accessibility on board played an important role in promoting satisfaction and health in the maritime industry [32].

In their research, Yuen et al. (2018) [33] aimed to analyse the main determinants of job satisfaction and performance of seafarers. They surveyed 116 officers and analysed the data obtained using structural equation modelling. They concluded that job satisfaction was significantly associated with seafarers' job performance. They also stated that the amount of stress associated with working onboard and the attractiveness of the rewards offered were the main determinants of job satisfaction. Finally, they presented a management model consisting of policies and strategies to motivate and retain seafarers [33].

In his study, Krystosik (2018) [34] explained some basic ergonomic factors in the engine room, bridge and other positions of a commercial ship and made ergonomic evaluations of the crew of the ship. In his work, he examined the importance of the physical arrangement of the bridgehead, factors such as noise, vibration, heat radiation (in the engine room), psychological stress and ergonomics. He also discussed the impact of working in confined spaces for extended periods and the impact of certain operating conditions of a ship. In addition, he analysed the psychological burden of working areas, working methods, and environmental factors on board. He presented the effects of certain marine environmental conditions on the psychology of the crew, such as confined work, lack of leisure space, long-term family and sociocultural separation and frequent changes in climatic conditions [34].

According to Tavacioglu et al. (2019) [23], using the Maslach Burnout Inventory (MBI) and the Minnesota Job Satisfaction Scale (MSQ), in their study with a total of 203 seafarers, 133 deck/engineering officers and 186 deck personnel, between the ages of 18 and 60, correlation analysis revealed a negative relationship between job satisfaction and burnout. The authors found that while burnout decreased for both deck and engine personnel, job satisfaction increased and vice versa. They also emphasized that the results showed that as happiness increased, job satisfaction increased and burnout decreased [23].

An et al. (2020) [35] published their work in 2020, aiming to empirically examine the effects of work-family conflict, job stress, and job satisfaction on seafarer performance. They collected the data from merchant ship sailors arriving at Yangshan Port in Shanghai, China [35].

In his study aiming to investigate the effects of demographic factors such as gender, marital status, age, experience and education level, on job satisfaction, Kandemir (2021) [36] collected data from people working on yachts in the Bodrum town of Muğla, using a survey method. According to the results of his study, no difference was found between marital status and job satisfaction. In addition, it has been concluded that age groups do not differ statistically in job satisfaction, that employees are more satisfied with their jobs as their age increases, and that job satisfaction increases as knowledge and experience increase. Finally, he stated that as the level of education increased, job satisfaction decreased, and as the level of education decreased, job satisfaction increased [36].

Yorulmaz and Sevinc (2021) [37] aimed to investigate the mediating role of work-family conflict and the moderator role of psychological resilience on yacht captains' perceived supervisor support and intention to leave during the COVID-19 epidemic. They concluded that perceived supervisor support had direct and indirect effects on intention to leave, with work-family conflict being a mediating variable. In addition, they also stated that the effect of work-family conflict on turnover intentions varied according to the psychological resilience levels of yacht captains [37].

As can be seen, there are studies of varying quality in the literature on personnel working at sea. A limited number of studies have been found on fatigue, burnout or job satisfaction among seafarers from the literature review in the field of maritime, while the number of studies on yacht personnel or yacht masters is much lower. Previous research shows that shipping involves high stress and serious risks. This study will enter the literature as the first research to evaluate the relationship between fatigue, job satisfaction and burnout levels among yacht masters. The number of these studies should be increased in order to provide more data richness in current and future studies.

METHODOLOGY

In this study, the burnout, satisfaction and fatigue levels of Turkish yacht masters were investigated with the Maslach Burnout Inventory (MBI), the Minnesota Job Satisfaction Scale (MSQ) and the Piper Fatigue Scale (PFS). Statistical analyses in the study were carried out using frequency and correlation analysis within the SPSS programme. A total of 68 Turkish yacht masters who are still actively working in the yacht tourism sector in the Bodrum region participated in the study. It is expected that the results of the study will provide specific outputs and guidelines for the relevant organizations dealing with yachting activities and offer suggestions for effective and efficient coordination between the relevant institutions.

The surveys were sampled by sharing them online via Google Forms (e-mail). In the first part of the research, demographic data such as gender, age, education, professional experience and the type of yacht they last worked on were collected from the yacht masters participating in the research. Following this, the participants answered a total of four sections, consisting of the MBI, MSQ and PFS measurement questionnaires.

The MBI questionnaire, which includes a socio-demographic information form used in this study, consists of 22 items and measures burnout related to the feelings and attitudes of professionals towards their jobs and staff [38]. Participants were asked questions on a 5-point Likert scale, with 1 meaning "never" and 5 meaning "always". MBI is divided into subscales that measure emotional exhaustion, depersonalisation and personal achievement dimensions. Emotional exhaustion refers to an individual's feelings of emotional exhaustion due to prolonged interaction with other people [39]. Questions 1, 2, 3, 6, 8, 13, 14, 16, and 20 in the questionnaire consist of 9 items measuring this emotional exhaustion. Depersonalisation is when employees treat the people they serve as objects, make derogatory remarks, and display an indifferent, cynical attitude [40]. Questions 5, 10, 11, 15 and 22 in the questionnaire consist of five items measuring this depersonalisation. Personal success defines a person's feelings of competence and success at work [41]. Questions 4, 7, 9, 12, 17, 19 and 21 in the questionnaire measure personal achievement dimensions (Fig. 1).

The MSQ scale consists of a 5-point Likert-type questionnaire with 20 items in which 1 means "I am not at all satisfied" and 5 means "Very satisfied". The first of the two sub-dimensions of the scale, inner satisfaction, consists of 12 questions and measures how employees feel about the job itself. In the questionnaire, internal factors correspond to questions 1, 2, 3, 4, 7, 8, 9, 10, 11, 15, 19, 20 [42]. The external factors, which are the second sub-dimension and evaluated with eight questions, reflect how the employees feel about the company. External factors are measured by the answers given to questions 5, 6, 12, 13, 14, 16, 17 and 18 [42]. In order not to mislead the participants and to make a correct analysis, three questions that did not fit the framework of the profession were excluded from the MSQ, taking into account the dynamics of the yacht captain's profession, which is the subject of the study. The questionnaire was applied to the participating masters in a way to include 17 questions (Fig. 2).

The Piper Fatigue Scale (PFS) was designed as a self-administered research tool to measure subjective patterns of fatigue in various populations [43]. PFS has four sub-dimensions. These are the behavioural violence sub-dimension consisting of six items covering questions 2, 3, 4, 5, 6, and 7; the emotional sub-dimension consisting of five items covering questions 8, 9, 10, 11, and 12; and the sensory sub-dimension consisting of five items covering questions 13, 14, 15, 16, and 17, and the cognitive mood sub-dimension consisting of five items covering questions 18, 19, 20, 21, and 22 [44]. The scale items also include measuring the distress caused by fatigue and the effect

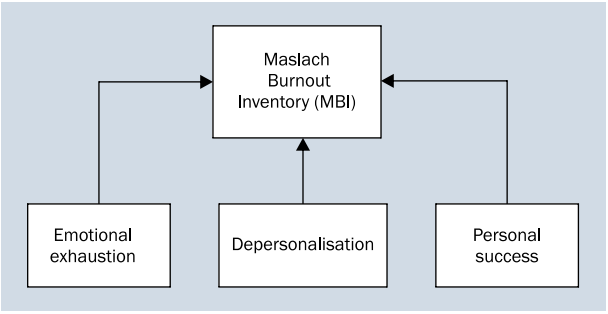

Figure 1. Maslach Burnout Inventory (MBI) model [38]

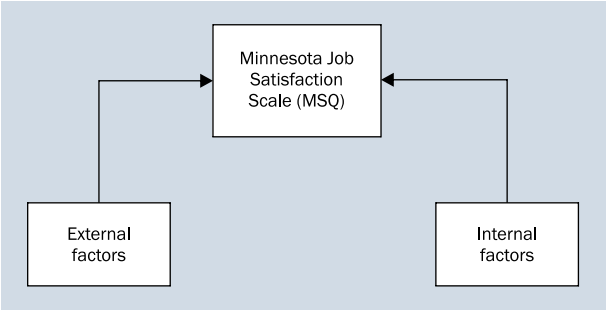

Figure 2. Minnesota Job Satisfaction Scale (MSQ) model [42]

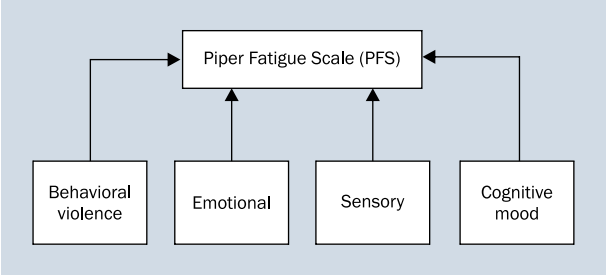

Figure 3. Piper Fatigue Scale (PFS) model [44]

of fatigue on activities of daily living. 22 items are scored on a numeric scale from "0" to "10" and the component items are averaged to calculate the four subscales and a Total Fatigue Score. As a result of the average scores; 0 points indicate no fatigue, 1–3 points indicate mild fatigue, 4–6 points indicate moderate and 7–10 points indicate severe fatigue (Fig. 3).

The SPSS (version 22.0) was used to analyse the data that was entered into the database. Pearson correlation analysis was performed to determine the relationships between the variables (Fig. 4).

The hypotheses based on the research model are as follows:

— H1: The relationship between age and level of job satisfaction;

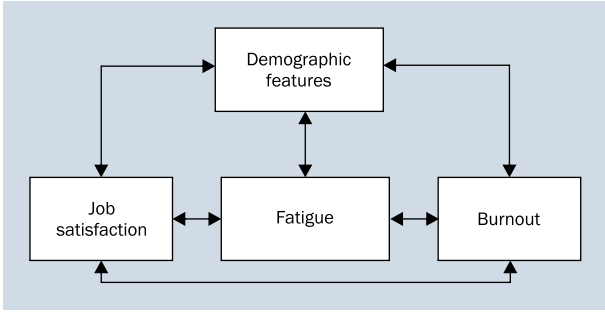

Figure 4. Model of the research

- H2: The relationship between age and fatigue level;
- H3: The relationship between age and burnout level;
- H4: The relationship between seniority in the profession and job satisfaction;
- H5: The relationship between seniority in the profession and the level of fatigue;
- H6: The relationship between seniority in the profession and the level of burnout;
- H7: The relationship between education level and job satisfaction, burnout, fatigue levels;
- H8: The relationship between job satisfaction level and fatigue level;
- H9: The relationship between job satisfaction and burnout;
- H10: The relationship between the level of fatigue and the level of burnout.

P-VALUE

Probability (p) value is a value used to determine the presence of statistical significance and the level of difference if any [45]. As a result of each statistical test, the p-value of the test statistic used is calculated. This p-value shows the probability of making an erroneous decision when it is said that "there is a significant difference in the result of the relevant hypothesis test". A value of p less than 0.05 is sufficient for the analysis to be considered statistically significant. The smaller p-value means the greater the evidence for rejecting the H0 hypothesis. The general approach to how to interpret the p-value [46] is given in Table 1.

FREQUENCY ANALYSIS

Frequency analysis is a statistical analysis technique that shows the frequency of observations and percentage distribution of data. In other words, it reveals the frequency of the variables quantitatively. According to the results of the frequency analysis, classification can be carried out depending on the frequency of the coded units and the items can be placed in order of importance [47].

Table 1. Statistical interpretation of the p-value [46]

P-value	Interpretation
$0.01 \leq p < 0.05$	Statistical significance
$0.001 \leq p < 0.01$	High statistical significance
$p < 0.001$	Very high statistical significance
$0.05 \leq p < 0.10$	Significance bias (borderline significance)
$p > 0.10$	The difference is due to coincidence (no statistically significant difference was found)

Table 2. Interpretation of correlation coefficients [49]

Correlation coefficients (r)	Level of relationship between variables
0.01–0.25	Very poor relationship
0.26–0.49	Poor relationship
0.50–0.69	Medium relationship
0.70–0.89	High relationship
0.90–1.0	Very high relationship

CORRELATION ANALYSIS

Correlation analysis was used to analyse the relationships between the variables in the study. In its broadest sense, correlation is a measure of the relationship between variables. In correlated data, a change in the magnitude of one variable is associated with a change in the magnitude of another variable in the same (positive correlation) or opposite (negative correlation) direction. Most of the time, the term correlation is used in the context of a linear relationship between two continuous variables and is expressed as a Pearson product-moment correlation. The Pearson correlation coefficient is typically used for data th at is jointly normally distributed, in other words, for data that follows a bivariate normal distribution. For non-normally-distributed continuous data, ordinal data, or data with associated outliers, Spearman rank correlation can be used as a measure of a monotonic relationship. Both correlation coefficients are scaled to range from –1 to +1; where 0 indicates there is no linear or monotonic relationship and the relationship gets stronger and eventually approaches a straight line (Pearson correlation) or an ever-increasing or decreasing curve [48]. In summary, the correlation coefficient (r) is the measure of the relationship between two variables and varies between –1 and +1.

The following definitions were made regarding the strength of the correlation coefficient (Table 2) [49].

APPLICATION

This study was applied to the yacht masters who were actually still working in Bodrum in October after the high season conditions. Considering the demographic characteristics of the yacht masters participating in the research, it is seen that 42% of the total is composed of masters between the ages of 31 and 40. In the gender distribution, it was determined that male masters were in the majority with 96%. When their educational status is examined, it is seen that 35% of them are high school graduates. The seniority of 37% of the participants as yacht masters is between 0 and 5 years. Seventy-six per cent of them stated that the yacht they were working at that time or had worked the last time was a private yacht (Table 3).

The reliability analysis of the research was determined by the Cronbach-Alpha values. According to Nunally and Brestein [50], it can be accepted that variables with an Alpha value of 0.70 and higher can be measured reliably. Cronbach's Alpha values of the scales used in the research were found to be quite reliable at 84% for the Maslach Burnout Scale (MBS), close to 93% for the Minnesota Job Satisfaction Scale (MSQ), and close to 97% for the Piper Fatigue Scale (PFS) (Table 4).

The SPSS (version 22.0) package programme was used in the analysis of the data. After the data was entered into the programme, normality research was carried out. The Kolmogorov-Smirnov test in the SPSS package programme was used to determine whether the data obtained in the research had a normal distribution or not, and the results are shown in Table 5.

When Table 5 is examined, it is seen that each scale data set has a normal distribution ($p > 0.05$). For this reason, parametric tests were applied in the analysis of the research.

According to the 5-point Likert scale, the average emotional exhaustion levels of the yacht masters participating in the research were 3.06 (± standard deviation 1.14), the average depersonalisation levels were 2.38 ± 0.90, and the average personal achievement levels were 4.11 ± 0.64, while the average general burnout levels were found to be 3.18 ± 0.62, and the values are shown in Table 6.

The average of the internal factors affecting job satisfaction of the yacht masters participating in the research, which is one of the sub-scales of the Minnesota Job Satisfaction Scale (MSQ), is 3.66 ± 0.86. According to the 5-point Likert scale, the average of the external factors affecting their job satisfaction is 3.21 ± 0.87. For general job satisfaction levels, the mean was found to be 3.44 ± 0.83 and the values are given in Table 7.

The average of the behavioural severity levels of the yacht masters participating in the study, which is one of

Table 3. Demographic frequency and percentage information of the participants

Demography	Frequency (n = 68)	Percentage (%)
Sex		
Male	65	96
Female	3	4
Age		
25 and below	12	18
26–30	10	15
31–35	14	21
36–40	14	21
41–45	9	13
46 and above	9	13
Education		
Primary education	3	4
High school	24	35
Vocational school	21	31
Licence	14	21
Graduate	6	9
Seniority as a yacht master		
0–5 years	25	37
6–10 years	9	13
11–15 years	20	30
16–20 years	5	7
21 years and above	9	13
Yacht type currently or last served		
Private	52	76
Charterer	16	24

Table 4. Reliability analysis results of the research

Scale used	Cronbach's alpha value
Maslach Burnout Inventory	0.841
Minnesota Job Satisfaction Scale	0.929
Piper Fatigue Scale	0.974

Table 5. Kolmogorov-Smirnov normality test results of the scales

Scale used	Statistics	P
Maslach Burnout Inventory	0.90	0.200
Minnesota Job Satisfaction Scale	0.107	0.051
Piper Fatigue Scale	0.70	0.200

the sub-scales of the Piper Fatigue Scale (PFS), was 5.75 ± ± 2.40 according to the 10-point Likert scale, the average of their emotional levels was 6.38 ± 2.06, and the average of their sensory level was 5.33 ± 2.44, the mean cognitive mood levels were 5.03 ± 2.58 and the mean general fatigue levels were 5.62 ± 2.30 found and the values are given in Table 8.

According to the results of the Pearson correlation analysis given in Table 9, there is a relationship between age and fatigue ($r = 0.264$, $p < 0.05$), burnout and job satisfaction ($r = 0.459$, $p < 0.01$) and fatigue (r) of the participating yacht masters. There is a statistically significant relationship between their job satisfaction and fatigue ($r = 0.616$, $p = 0.01$). There is a negative relationship between age and fatigue, burnout and job satisfaction, and job satisfaction and fatigue among yacht masters participating in the research. On the contrary, there is a positive relationship between their fatigue and their job satisfaction. Professional seniority increases with age. As a result, a statistically significant and positive relationship between yacht masters' age and professional seniority ($r = 0.673$, $p = 0.01$) is expected. No significant relationship was found between other variables. Since there were not enough ($n = 3$) female employees in our data set to affect the analysis, the distribution of analyses by gender could not be investigated.

Table 10 shows the significance levels of the 10 tested hypotheses according to the results of the Pearson correlation analysis used to test the predicted research hypotheses, and whether the theories are supported or not.

There is a weak relationship between the age and fatigue levels of the yacht masters participating in the research, and their fatigue levels decrease as their age increases ($r = 0.264$). A moderate relationship was found between job satisfaction levels and fatigue levels, and a weak relationship between burnout levels, namely that as job satisfaction levels increase, fatigue levels decrease ($r = -0.616$). In addition, as job satisfaction levels increase, burnout levels decrease ($r = -0.459$). A moderate relationship was determined between fatigue and burnout levels; as fatigue levels increase, burnout levels increase ($r = 0.621$).

In addition, no relationship was found between the age of the masters and their job satisfaction or burnout levels. Also, no statistical relationship was found between professional seniority and job satisfaction, fatigue levels or burnout levels. Similarly, no relationship was found between the education levels of the masters and their job satisfaction, burnout and fatigue levels.

Table 6. Descriptive statistics of the participants' levels of burnout according to the Maslach Burnout Scale and its subscales

Burnout and subscales	N	SD	$\bar{X}$
Emotional exhaustion	68	1.14	3.06
Depersonalisation	68	0.90	2.38
Personal success	68	0.64	4.11
Maslach Burnout Inventory	68	0.62	3.18

Table 7. Descriptive statistics of participants' job satisfaction levels according to the Minnesota Job Satisfaction Scale and its subscales

Job satisfaction and subscales	N	SD	$\bar{X}$
Internal factors	68	0.86	3.66
External factors	68	0.87	3.21
Minnesota Job Satisfaction Scale	68	0.83	3.44

Table 8. Descriptive statistics of participants' levels of fatigue according to the Piper Fatigue Scale and subscales

Fatigue and subscales	N	SD	$\bar{X}$
Behavioural violence	68	2.40	5.75
Emotional	68	2.06	6.38
Sensory	68	2.44	5.33
Cognitive mood	68	2.58	5.03
Piper Fatigue Scale	68	2.30	5.62

RESULTS AND DISCUSSION

This study was aimed to evaluate the relationship between fatigue, job satisfaction and burnout levels among yacht masters and offer solutions based on the findings.

Table 9. Correlation analyses between participants' demographic characteristics, burnout, job satisfaction and fatigue

	1	2	3	4	5
1. Age	1				
2. Education status	–0.057	1			
3. Seniority in the profession	0.673**	–0.052	1		
4. Burnout	–0.184	–0.002	-0.014	1	
5. Job satisfaction	0.223	–0.094	0.173	–0.459**	1
6. Fatigue	–0.264*	0.102	–0.145	0.621**	–0.616**

*p < 0.05; **p < 0.01

Table 10. Supported/unsupported status of research hypotheses

Hypotheses	Supported/unsupported	Significance level
H1: The relationship between age and job satisfaction level	Unsupported	
H2: The relationship between age and fatigue level	Negatively supported	$p < 0.05$
H3: The relationship between age and burnout level	Unsupported	
H4: The relationship between seniority in the profession and job satisfaction	Unsupported	
H5: The relationship between seniority in the profession and the level of fatigue	Unsupported	
H6: The relationship between seniority in the profession and the level of burnout	Unsupported	
H7: The relationship between education level and job satisfaction, burnout, fatigue levels	Unsupported	
H8: The relationship between job satisfaction level and fatigue level	Negatively supported	$p < 0.01$
H9: The relationship between job satisfaction and burnout	Negatively supported	$p < 0.01$
H10: The relationship between the level of fatigue and the level of burnout	Supported	$p < 0.01$

In the study, yacht masters' perceptions of emotional burnout due to their long-term interactions with other people were found to be high ($\bar{X}$ = 3.06, SD = 1.14), while their perceptions of competence and success in their jobs were found to be very high ($\bar{X}$ = 4.11, SD = 0.64). The levels of treating the people they serve like objects, making derogatory remarks, and displaying an indifferent and sarcastic attitude was low ($\bar{X}$ = 2.38, SD = 0.90), while their general burnout level was high ($\bar{X}$ = 3.18, SD = 0.62).

Due to the nature of the yachting business, yacht masters have more relationships with the crew and guests on board the yacht than with the yacht operators. As a result, external factors related to the business less affect the masters' job satisfaction. The general job satisfaction ($\bar{X}$ = 3.44, SD = 0.83) of the yacht masters subjected to the research was found to be at a high level. What they feel about the job itself, namely internal factors ($\bar{X}$ = 3.66, SD = 0.86), affects their job satisfaction more than how masters feel about the business, namely external factors ($\bar{X}$ = 3.21, SD = 0.87). It is recommended that yacht owners or yacht operators focus on improving the quality of the work environment onboard in order to increase their captain's job satisfaction.

The general fatigue levels of the masters ($\bar{X}$ = 5.62, SD = 2.30) were found to be moderate. Among the subscales that make up the general fatigue levels, emotional levels ($\bar{X}$ = 6.38, SD = 2.06) were found to be close to high, and behavioural violence levels ($\bar{X}$ = 5.75, SD = 2.40), sensory levels ($\bar{X}$ = 5.33, SD = 2.44) and cognitive mood levels ($\bar{X}$ = 5.03, SD = 2.58) were found to be moderate.

Wu et al. (2014) [51] stated that being away from home and loved ones, fatigue, long working hours, limited space, insufficient sleep and multinational factors made working on a yacht difficult and complex. Sanchez-Beaskoetxea and Garcia (2015) [52] stated that an employee who was satisfied with his job would outperform his dissatisfied colleague. Furthermore, according to their research, a satisfied employee makes fewer mistakes at work, is more productive, and is more likely to stay with the organization [52]. According to other results of this research, as the satisfaction rates of yacht masters increase, their perceived fatigue levels decrease. In other words, low burnout tendencies have a positive effect on seafarers' job satisfaction. Other studies in the literature also support this [23, 28, 33]. Yacht owners should make the necessary efforts and provide the necessary opportunities to have yacht masters who are satisfied with their jobs.

As masters' professional experience increases, their ability to manage fatigue and professionally accept fatigue can increase. This is also effective in reducing the fatigue perception levels of masters at advanced ages. Bridger et al. (2010) [53] also concluded that similar to the findings of this study, older staff could cope with the daily demands of working life compared to younger staff, possibly due to a "survival effect". It will be beneficial for the sector to ensure that the masters perform their profession for a long time. In order to achieve this goal, it is necessary to increase the satisfaction of the employees in their jobs.

For the sake of work efficiency, yachts often operate with a minimum crew level, which means that yacht personnel, including the captain, have to work long hours. As a result, the minimum crew level on yachts is causing seafarers fatigue in conjunction with the busy working hours. According to another finding of the study, in parallel with other studies in the literature [54–56], the burnout levels of yacht masters increase as their fatigue levels increase. In order to reduce fatigue levels, it is necessary to increase the rest periods of all yacht personnel, including the captain, and to make the daily working hours comply with the International Labour Organization (ILO) and IMO norms.

CONCLUSIONS

In future studies, it is recommended to use other multi-criteria decision-making models and different scales to determine the fatigue levels, job satisfaction and burnout levels of yacht masters, and to evaluate these studies on a larger group of yacht masters with more female masters participating in different yacht types. Thus, more reliable results can be revealed through comparative analysis and the problems will be more clearly understood.

Conflict of interest: None declared

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CASE REPORT

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Scalp laceration repair with hair apposition technique in the maritime environment under telemedicine guidance using free open-access medical resources

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ABSTRACT

Requests for medical advice to evaluate injuries sustained on board a shipping vessel make up a significant number of calls to Telemedical Maritime Assistance Services. As the maritime setting is an austere environment with regards to resources such as equipment and availability of medically trained personnel, it is important to have a set of skills and techniques to treat all manner of common injuries with the tools at hand. Here we discuss a case report of using telemedicine and free open-access medical education resources to teach the hair apposition technique to an on-board medical provider for the treatment of a scalp laceration with good outcome.

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Key words: telemedicine, maritime, hair apposition technique

INTRODUCTION

Evaluating and treating injuries at sea comes with a unique set of challenges, including finite resources, varying levels of medical training for providers on board, and communication limitations with expert providers ashore. Additionally, definitive care for injuries may be days or weeks away. Delaying injury care may be detrimental to the injured, including in situations where prompt laceration closure is required. Delayed laceration repair can lead to increased bleeding and pain, wound infection, and poor cosmetic outcomes. Additionally, diverting or evacuating and repatriating an ill mariner can carry significant cost [1]. Telemedical Maritime Assistance Services provide an avenue for shipboard crew to seek out medical advice from shore-based expert medical providers, who can communicate medical advice to onboard crew and assist with decisions about treating on board or evacuating the mariner.

The incidence of emergency department visits for wounds or lacerations has been estimated to be about 12 million visits per year [2]. It is difficult to estimate the incidence of these injuries at sea due to multiple factors, including a heavily rotating workforce, assumed underreporting of injuries, and varying standards of diagnosis and care.

Case series estimate that between 17% and 32% of all maritime telemedicine calls are for injury evaluation [3, 4]. Management of these injuries is complicated by wide variations in available medical equipment on ships and by crew difficulty maintaining procedural skills to a sufficient level to treat. Improvisation and re-purposing of equipment can be used to make up for equipment shortfalls, and pictures, written material, instruction, and on-line video (when bandwidth permits) may be used to make up for procedural skill shortfalls.

We describe a case for which email-only, or asynchronous telemedicine was used in conjunction with a free open-access medical (FOAM) education resource to instruct crew at-sea on the use of the hair apposition technique (HAT) in scalp laceration repair for an injury sustained at sea.

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Figure 1. Laceration at the time of consult

Figure 2. Laceration at the time of repair

CASE REPORT

A 32-year-old male crewmember on a small cruise ship sustained a head laceration (Fig. 1) approximately 5 cm long when a pot lid fell on his head. A telemedicine consult was made approximately 12 hours after the initial injury. There was no loss of consciousness, neck pain, or neurological deficit. Bleeding was controlled by the time of the initial consultation. The ship was 1–2 days from port. The vessel was carrying a commercially available medical kit which had supplies for wound care, including cleaning supplies, dressings, and skin closure strips. The kit did not contain sutures, skin glue, or skin staples.

After understanding the mechanism of injury and gathering information to complete a brief neurological exam, the consulting physician suggested copious irrigation and closure using the hair apposition technique to close the wound. A FOAM resource was shared with the ship's medical officer, who completed wound closure using the technique [5]. The medical officer used a commercial super-glue to complete the technique because the ship did not carry a medical adhesive.

Follow-up photos were obtained immediately after closure (Fig. 2) and at 10 days (Fig. 3). The wound healed well and there were no complications.

Figure 3. Laceration after 10 days

DISCUSSION

Lacerations are an extremely frequent injury leading people to seek out emergency care. In the outdoors recreational setting, lacerations account for approximately 14,800 out of every 100,000 injuries, and lead to approximately 12 million emergency department visits per year [2, 6].

The high frequency of injuries occurring in the austere environment highlights the importance of disseminating appropriate information for the proper treatment of scalp lacerations. The case highlighted above took place on a small cruise ship far from port with limited equipment and expertise to carry out the repair. The hair apposition technique was suggested due to its simplicity and minimal equipment requirement.

The technique has been studied for use in multiple settings, including the emergency department [2, 7–11], austere environments [6, 12], and by different types of healthcare providers [10], overall noting non-inferiority, if not

superiority as compared to typical wound closure techniques such as suture, staples, or tissue adhesives. The technique is easy to teach in less than a half hour [8, 10] and had similar outcomes between emergency department physicians and nurses [10]. HAT is inexpensive to perform, requires little more than the skill of the practitioner and the use of an appropriate adhesive, and does not require painful removal of wound closure equipment left in situ, such as sutures or staples, nor the injection of a local anaesthetic [8, 9]. Variations exist for HAT, including the modified HAT developed in Turkey, which utilises surgical instruments to bundle and secure hair to bring a scalp laceration together [7]. The technique was used in this case with a satisfactory outcome and with no complications.

As no video was available to directly and synchronously guide the ship's medical officer, FOAM literature was distributed, along with verbal instructions to treat this injury. FOAM resources entail "a collection of interactive online medical education resources — free and accessible to students, physicians, and other learners" [13]. FOAM uses social media, podcasts, tweets, and other web-based resources to allow dissemination and deliberation of emerging scientific and medical research [14]. In the FOAM paradigm, these resources have been used by members of the medical community as a tool to share rapidly emerging concepts [15].

Those who provide care in austere environments or on a part-time basis may need to treat injuries or illnesses that were not directly covered over the course of their medical training. Free open-access medical education can be a great boon to medical and health professions students as well as those practicing in the austere environment (including critical access hospitals, rural settings and low resource settings), who may need to infrequently call on a broad breadth and depth in medical skills across many fields.

In this case a FOAM resource was used in a novel way to allow an experienced physician to assist a ship's medical officer, who had limited experience, to properly treat an injury. Scalp lacerations have a wide range of undesirable outcomes, such as scar formation, poor cosmesis, and infection, hence it is important that they be promptly and definitively repaired and treated. Layperson use of FOAM resources to treat injury in a resource-limited austere setting, with vetting and guidance from an experienced physician, may be an emerging future use as FOAM matures.

CONCLUSIONS

In individuals with an appropriate amount of hair, scalp lacerations in a variety of settings, including the austere environment, can be appropriately managed with minimal equipment and training using the hair apposition technique. FOAM can serve as a source of easily available and sharable content for medical providers in austere locations to be used under the guidance of a telemedicine physician.

Conflict of interest: None declared

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CASE REPORT

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Challenges in the diagnosis and treatment of malaria in Polish workers returning from Africa: a case series and review of literature

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ABSTRACT

Malaria is a parasitic disease caused in humans by five species of Plasmodium: P. falciparum, P. vivax, P. malariae, P. ovale, and P. knowlesi and transmitted through a female mosquito bite. In 2020, there were 241 million cases of malaria worldwide including 627,000 deaths. Traveling to malaria endemic areas is a significant risk factor, therefore, it is very important to use non-specific and pharmacological prophylaxis. Malaria symptoms usually appear 10–14 days after infection and the disease may be suspected, based on patient examination and medical history, in patients with fever who have stayed in malaria endemic areas. The initial symptoms of the disease are not pathognomonic and it is important to remember that not all malaria patients develop a fever. A prerequisite for successful treatment of this potentially life-threatening disease is well-targeted, timely diagnosis and immediate implementation of antiparasitic therapy. Despite significant progress in the fight against malaria across the world, the disease still poses a diagnostic and therapeutic challenge, especially when it develops as a result of an imported infection and when diagnosis is complicated by the presence of other diseases. A professional group that requires special attention are maritime workers.
In this study we present clinical cases of malaria which show how important it is in the clinical practice of various specialists to include malaria in the differential diagnosis of patients with fever returning from tropical regions.

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Key words: *Plasmodium*, malaria, fever, tropical medicine

INTRODUCTION

Malaria is a parasitic disease caused in humans by five species of *Plasmodium*: *P. falciparum*, *P. vivax*, *P. malariae*, *P. ovale*, and *P. knowlesi* [1]. The disease is transmitted through a female *Anopheles* mosquito bite, when the insect pierces human skin with its stylet and introduces sporozoites (forms of *Plasmodium* that are invasive to humans) into the human bloodstream. Infection can also occur through blood transfusion and vertical route from mother to child (placenta) [2]. The life

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cycle of *Anopheles* mosquitoes (infection vector) is dependent on climatic conditions. The most favorable conditions include the temperatures from 16 °C to 33 °C [3], altitude up to a maximum of 2000–2500 m above sea level and air humidity above 60%. The presence of water bodies is also essential for mosquitoes to reproduce. Of the species of pathogenic parasites, the most dangerous to humans is *Plasmodium falciparum*, which can cause severe malaria [4].

There have also been reports of a *Plasmodium* infection in people who have never been to a malaria-endemic area. Airport and harbor malaria is a specific form of indigenous malaria, when an *Anopheles* mosquito infected with *Plasmodium* travels, for example in luggage, from an endemic area to a country where the disease is absent. Although airport and port malaria is rare (only 33 cases from 1969 to 2020 have been reported in the literature), an upward trend in the incidence has been observed in the last decade. More than a half of the confirmed cases took place in Europe [5], including France, Belgium, Switzerland and Spain [2, 6, 7]. This type of malaria commonly occurs in the summer months (July, August), during which time in southern Europe there is a climate similar to that of endemic regions. Although airport malaria is rare, the apparent absence of a history of risk factors may result in a delay in diagnosis and, consequently, in appropriate treatment of the patient [8].

It should also be remembered that even a short stay in an area where malaria vectors are present, such as an airport, when transferring to a connecting flight, may result in a *Plasmodium* infection [2, 5].

EPIDEMIOLOGY

In 2020, there were 241 million cases of malaria worldwide, compared with 227 million in 2019. The vast majority of cases (95%) were reported in Africa, followed by Southeast Asia (2.0%; 5 million), and the Eastern Mediterranean (2.3%; 5.7 million). More than 50% of the reported malaria cases occurred in six African countries: Nigeria (27%), the Democratic Republic of the Congo (12%), Uganda (5%), Mozambique (4%), Angola (3.4%), and Burkina Faso (3.4%).

In 2020, there were 627,000 deaths from malaria, compared with 405,000 deaths in 2018 and 558,000 deaths in 2019 [9, 10].

CLINICAL PICTURE

Symptoms of the disease usually appear 10–14 days after infection. In over 90% of patients, malaria occurs within a month after travel, although it may appear as late as even several months after returning from the endemic regions [11, 12].

Malaria may be suspected, based on patient examination and medical history, in patients with fever who have stayed in malaria endemic areas. The initial symptoms of the disease are not pathognomonic. Apart from fever, they may include: tachycardia, tachypnea, chills, general weakness, fatigue, excessive sweating, headache, cough, lack of appetite, nausea, vomiting, abdominal pain, jaundice, diarrhea, and muscle aches. It should be noted that not all malaria patients develop a fever [13]. Uncomplicated malaria is diagnosed in patients with mild symptoms, and it is confirmed by parasitological tests. Rapid immunochromatographic tests based on the detection of *Plasmodium* antigens may be useful, although because of their low sensitivity a negative result does not exclude malaria. On physical examination, signs of anemia and enlargement of the liver and spleen can be expected. A prerequisite for successful treatment of this potentially life-threatening disease is well-targeted, timely diagnosis and immediate implementation of antiparasitic therapy.

BUSINESS TRAVELERS

Traveling to malaria endemic areas is a significant risk factor. Protection against malaria in travelers to endemic countries (including business travelers) includes non-specific prophylaxis, i.e., protection against mosquito bites, and pharmacological prophylaxis.

Unfortunately, despite the rapid development of tropical medicine and increase in international arrivals, a significant proportion of travelers fail to adhere to the principles of prevention. A study conducted among workers posted to Zambia and Ghana showed that the principles of prophylaxis were only followed by 44% and 11% of the respondents, respectively [14]. Of all the United States residents hospitalized due to malaria only 23% reported that they respected the principles of prophylaxis while staying in endemic areas [15]. A similar result was obtained in a study conducted in Switzerland. The study demonstrated that only about 16% of people traveling to high-risk areas on business adhered to chemoprophylaxis in combination with personal protective measures. Unfortunately, this study also showed a lack of knowledge of the disease symptoms and its incubation period [14]. Interestingly, a survey conducted among missionaries working in Zaire revealed that approximately 62% of the respondents adhered to chemoprophylaxis of malaria, which was the highest rate of compliance in travelers to areas with high risk of malaria transmission reported to date [16].

The authors present cases showing difficulties in diagnosing and treating malaria in people returning from work trips to Africa.

CASE 1

A 27-year-old patient, a mechanic on a ship, who had previously stayed in Sierra Leone for 4 months, was admitted to the Department of Tropical and Parasitic Diseases in

Gdynia, Poland due to a fever of up to 40 °C accompanied by chills, weakness, muscle pain and headache. The symptoms occurred 6 days after returning to Poland. The patient denied abdominal pain, diarrhea, vomiting or cough. Before being admitted to our hospital, the patient was consulted by a doctor several times, but he was not tested for malaria.

The medical interview revealed that the patient had an open fracture of the right lower leg, which occurred in Sierra Leone 20 days before his return to Poland. The patient underwent surgical treatment at a local hospital in Sierra Leone and received antibiotic therapy (ceftriaxone, gentamicin, metronidazole).

While working on the ship the patient was taking malaria chemoprophylaxis (he did not remember the name of the drug), but it was discontinued during the hospitalization after the lower limb injury.

On admission, the general condition of the patient was fair. He had low blood pressure (95/55 mmHg), heart rate of 76/min, and fever (38.6 °C).

Physical examination revealed a fine blotchy rash and an oozing wound on the right lower leg, with a visible metal frame of the external fixation of the fractured bone. The patient was consulted by an orthopedist who did not find any evidence of wound infection.

Laboratory test results were as follows: elevated levels of procalcitonin (95.24 ng/mL), C-reactive protein (CRP; 63.8 mg/L), creatinine (1.64 mg/dL), D-dimer (5020 ng/mL), alanine aminotransferase (ALT; 53 U/L), and gamma-glutamyl transpeptidase (123 U/L), decreased platelet count (57 G/L) and hemoglobin concentration (11.5 g/dL). The rapid test for malaria was positive for *Plasmodium falciparum*; direct microscopic examination of the blood (thin and thick smears) revealed numerous rings of *Plasmodium falciparum*. Blood, urine, and wound swab cultures were negative. Serological tests for dengue showed presence of IgM- (36.2 NTU) and IgG-class (11.4 NTU) antibodies.

Abdominal ultrasound revealed splenomegaly (149 mm), a normoechogenic liver with the right lobe length of 140 mm and a lymph node measuring 13 × 6 mm in the hilum. Chest X-ray showed increased interstitial lung markings, and bronchitis was suspected.

During hospitalization, the treatment with artesunate at a dose of 2.4 mg/kg body weight/day and doxycycline at a dose of 200 mg/day was administered, followed by a combination of artemether with lumefantrine (20 mg/120 mg tablets) administered 4 tablets twice a day for 3 days. In addition, the patient received piperacillin with tazobactam, low molecular weight heparin, as well as antipyretic and hepatoprotective drugs.

The treatment resulted in a significant improvement in the patient's condition, a decrease in inflammatory parameters (CRP 8.7 mg/L, procalcitonin 2 ng/mL) and blood smear negativization. The patient was discharged home in good condition, without fever. There were no recurrences of the disease in the follow-up.

CASE 2

A 51-year-old patient was transferred to the Department of Tropical and Parasitic Diseases in Gdynia, Poland from the Emergency Department of the Specialist Hospital due to the diagnosis of malaria. Six days earlier, the patient had returned from Africa (Guinea), where he had stayed on business for 2 months. The patient was taking antimalarial prophylaxis (proguanil with chloroquine), but not regularly. During his stay in Africa, 3 days before his return to Poland, he had a motorcycle accident in which his left thigh was injured, resulting in the formation of a fluid collection. The patient had a fever of up to 40 °C for 5 days. During this time, he was twice referred for observation/consultation in the Hospital Emergency Department where the fluid collection in the thigh was evacuated twice (clear, colorless fluid). Amoxicillin/clavulanic acid was recommended and the patient was referred to outpatient care. Diagnostic tests for malaria were not performed, although the patient reported a stay in an endemic area. The tests performed during the second visit to the Hospital Emergency Department revealed the presence of *Plasmodium* schizonts in the blood smear.

On admission to our Department, the patient was in fair general condition, hemodynamically and respiratory stable, with good verbal response, and fever up to 39 °C. Physical examination revealed a fluid collection on the left thigh without signs of inflammation, and abrasions on the left upper limb. Laboratory test results were as follows: positive rapid malaria test (*Plasmodium falciparum*), anemia (12.5 g/dL), thrombocytopenia (48 g/L), elevated concentration of both CRP (218 mg/dL) and D-dimer (6512 ng/mL). Direct blood test (thick and thin smears) showed *P. falciparum* rings; parasitemia was 20%. A polymerase chain reaction test for malaria was positive for *P. falciparum*. No dengue-specific IgM- and IgG-class antibodies were detected by the serological test. Abdominal ultrasound showed an enlarged liver (160 mm) and spleen (157 mm) as well as an enlarged prostate with fibrosis. Chest X-ray showed no abnormality.

Treatment with artesunate at a dose of 2.4 mg/kg body weight in a five-dose regimen (0, 12, 24, 48, and 72 hours) and clindamycin at a dose of 1800 mg/day was administered. On the first day of treatment, the patient had a fever of up to 39 °C; he was agitated and restless, and had delayed verbal response. Saturation dropped to 88% and dark-colored urine was observed. Reassessment of laboratory parameters showed worsening of anemia (9.5 g/dL), hyperbilirubinemia (3.46 mg/dL),

high lactate dehydrogenase activity (811 U/L). Testing for glucose-6-phosphate dehydrogenase (G-6-PD) deficiency (7.7 U/g of Hb, normal range: 7–20.5) was ordered. A significant decrease in parasitemia was found in subsequent blood smears. The artesunate treatment was completed and the treatment was continued with a combination of artemether with lumefantrine (20 mg/120 mg tablets) administered 4 tablets twice a day for 3 days. Blood smears for malaria were negative. Improvement in the patient's clinical condition and laboratory parameters was observed. Due to the fact that the fluid collection on the left thigh was still present, a surgical consultation was provided — suction drainage in the surgical department was recommended.

CASE 3

A 23-year-old patient was transferred to the Department of Tropical and Parasitic Diseases in Gdynia from the Surgical Department (where he had stayed for 10 days) with suspicion of malaria. The patient had an accident at work on a ship in Sierra Leone about 3 weeks earlier (fracture of the humerus and soft tissue injury to the right arm, and injury to the right half of the chest). During hospitalization in Sierra Leone, thoracotomy and lower lobectomy of the right lung as well as external anastomosis of the fractures of the humerus were performed. The day before returning to Poland, the patient developed a fever above 39 °C with accompanying shivers and general weakness.

In Poland, he was admitted to the Department of Surgery, where he was diagnosed with: status post (S/P) multi-organ trauma, S/P lobectomy of the lower right lung, S/P external osteosynthesis of the right humerus, S/P skinning of the right arm area and autologous middle-thickness skin transplantation in this area, residual right-sided pneumothorax, residual hematoma of the right pleural cavity with a slight postoperative atelectasis of the right lung. Due to the persistent fever, malaria was suspected.

On admission to our department, the general condition of the patient was fair. The patient manifested the following symptoms: fever above 40 °C, chills, profuse sweating, lack of appetite. A physical examination revealed the scar after right-sided thoracotomy, the metal frame of the external osteosynthesis of the right humerus, the scar on the right thigh and the healing wound on the right shoulder after autologous skin transplantation. In addition, the patient was exhausted (he lost about 11 kg in a month) and was reluctant to leave the bed/perform any physical activity.

The following results were obtained from laboratory tests: a positive rapid malaria test (*P. falciparum*), anemia (10.5 g/dL), thrombocytopenia (84 G/L), increased CRP concentration (56 mg/L), increased D-dimer concentration (2299 ng/mL), increased ALT activity (111 U/L) and decreased albumin level (23.8 g/L). Direct blood test (thick and thin smears) revealed *P. falciparum* rings and gametocytes with parasitemia of about 1.5%.

Ultrasound examination of the abdominal cavity revealed an enlarged spleen (155 × 70 mm). Chest X-ray showed fluid in the pleural cavity and a raised diaphragm on the right side, visible shadowing of the lower field above the fluid corresponding to atelectasis, and areas of parenchymal consolidation probably corresponding to postoperative lesions.

Malaria treatment with artesunate with doxycycline was initiated, followed by a combination of artemether with lumefantrine; antibiotic therapy with amikacin, which was started in the Surgical Department, was continued. The fever subsided and the patient's clinical condition improved significantly. Pulmonary rehabilitation was started, which improved the dynamics of breathing. The patient was discharged home in good general condition, without fever. There were no recurrences of the disease in the follow-up.

DISCUSSION

Among the mosquito-borne diseases, malaria remains a major health concern in tropical regions around the world. The above cases show how important it is in the clinical practice of various specialists to include malaria in the differential diagnosis of patients with fever returning from tropical regions (including overseas workers). This is particularly important considering that these patients are not immediately referred to one of the few centers in Poland specializing in the treatment of tropical diseases. Every physician, regardless of their specialization, should be aware that diagnostic tests to exclude or confirm a *Plasmodium* infection are necessary in people who have recently returned from malaria-endemic areas. Unfortunately, the diagnosis of malaria in Poland is still a challenge for diagnosticians and doctors. In all the above described cases diagnosis of malaria was delayed from 6 to 10 days, which in case of an infection with *Plasmodium falciparum* may result in severe and life threatening complications.

According to the data from the GeoSentinel network published in 2017, more than a half (53%) of travelers diagnosed with malaria visited friends and relatives. The majority (83%) were exposed in sub-Saharan Africa. The median duration of the trip was 32 days; 53% did not have a pre-travel consultation. More than a half of the patients (62%) were hospitalized, and the majority of those hospitalized were children. The most commonly identified species was *P. falciparum*. However, more than 40% of travelers who stayed in a malaria-affected region for ≤ 7 days were found to be infected with *P. vivax* [17].

Laboratory findings that are characteristic of malaria include the presence of parasites in direct blood tests, anemia, thrombocytopenia, increased activities of transaminases, mild coagulopathies, and increased levels of urea and creatinine. Severe malaria is defined as malaria caused by *Plasmodium falciparum* [4] (parasitemia > 10%; > 500,000/microliter of blood) [11, 18] with one or more of the following symptoms: impaired consciousness (assessed according to the Glasgow scale), extreme fatigue (the patient cannot sit up, stand up or walk without assistance), seizures (more than 2 episodes in 24 hours), and laboratory abnormalities: metabolic acidosis, hypoglycemia, severe anemia or massive intravascular hemolysis, coagulation disorders, including disseminated intravascular coagulation, impaired kidney function, liver damage and/or jaundice (bilirubin > 3 mg/dL), pulmonary edema/acute respiratory distress syndrome, significant bleeding (e.g. nosebleed, bleeding gums, bloody vomiting, or stools), shock (systolic blood pressure < 70 mmHg).

The differential diagnosis of malaria should include dengue, chikungunya, meningitis, pneumonia, bacteremia, typhoid fever, leptospirosis, and viral hemorrhagic fever [19].

A delay in the diagnosis and treatment of malaria can lead to an increased number of complications and increased mortality from the disease. In uncomplicated cases, patients can be treated with oral antimalarials. In severe malaria, immediate initiation of intravenous treatment (optimally with monitoring for parasitemia) is essential. Artesunate or, when intravenous administration is not possible, intramuscular artemether is the preferred drug [9, 11]. If artemether is not available intravenous quinine or quinidine may be recommended. Artemisinin derivatives reduce parasitemia in a shorter time and are associated with a statistically significant reduction in mortality compared with quinine [18].

When collecting a medical history, it is extremely important to carefully review the travel history as well as details of the prophylaxis and vaccinations. The possibility of co-occurrence of other internal diseases with *Plasmodium* infection should also be taken into account.

In the 1970s, Europe was declared free from endemic malaria (Poland was certified malaria-free in 1967) [20]. However, the climate change favors the spread of mosquitoes and parasites. Increased economic migration, the influx of refugees and migrants from endemic areas may contribute to the formation of *Plasmodium* reservoirs in areas previously free from malaria. Since 2009, native malaria has been reported in Greece and isolated cases of malaria were reported in Spain, Italy and France [3].

Due to the development of tourism and increasing population migration, the disease is becoming a major health issue globally, including in Poland.

CONCLUSIONS

Despite significant progress in the fight against malaria across the world, the disease still poses a diagnostic and therapeutic challenge, especially when it develops as a result of an imported infection and when diagnosis is complicated by the presence of other diseases. A professional group that requires special attention are maritime workers.

Conflict of interest: None declared

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LETTER TO THE EDITOR

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Hyperbaric oxygen therapy in necrotizing soft tissue infections caused by Vibrio species from the Baltic Sea — three clinical cases

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We read with great interest the report on the presence of *Vibrio spp* in the Gulf of Gdansk, Baltic Sea, Poland by Kurpas et al. [1]. So far, the vast majority of identifications of *Vibrio spp* in open waters concerned the subtropical zone. In an analysis of 19 publications describing 2,227 patients with NSTI caused by *Vibrio vulnificus*, 95% of cases concerned such subtropical zones [2]. However, there are also reports describing the changing location of *Vibrio*, mainly due to the gradual increase in open water temperature [3]. The identification of *Vibrio spp* in the climatic zone of the Baltic Sea is a new observation that is of great importance not only from the microbiological point of view but also for clinical reasons.

Vibrio is one of the more common bacteria in tropical or subtropical waters. It is a gram-negative rod that can cause necrotizing soft tissue infection (NSTI), which also includes necrotizing fasciitis, and often leads to septic shock and an immediate threat to life. From the aetiology point of view, NSTI most often has a polymicrobial aetiology, often described as type I, or monomicrobial, usually described as type II (most often caused by group A beta-haemolytic streptococci, e.g. *Streptococcus pyogenes*), sometimes in combination with *Staphylococcus aureus* [4, 5]. According to the same classification, infections caused by *Vibrio spp* are referred to as type III related to other less common causative agents (e.g., *Clostridium spp*, *Aeromonas spp*, *Vibrio spp*). Type IV describes fungal infections (e.g., *Candida spp*, *Zygomycetes*). Regardless of aetiology, the treatment of any form of NSTI is multimodal and includes surgery, antibiotic therapy, and haemodynamic sepsis management [4–8]. In the case of Vibrio NSTI, the importance of surgical interventions is emphasized [9]. Most of the recommendations also suggest using hyperbaric oxygen therapy (HBOT). In the literature, one can find descriptions of clinical cases successfully treated with HBOT, but in most of those reports the infections came from sub-tropical waters of the United States or Japan [10, 11].

An interesting coincidence is a fact that at almost the same time as the publication by Kurpas et al. [1] on the occurrence of *Vibrio spp* in the Gulf of Gdansk, a clinical case report of a 68-year-old patient with NSTI caused by *Vibrio vulnificus*, most probably from the south-western part of the Baltic Sea, treated with adjunctive HBOT in our department was published [12]. In summary, after injuring while swimming in Baltic seawater, the patient developed NSTI of the lower extremity. *Vibrio vulnificus* was identified in blood. Initially, this patient was treated in a local municipal hospital. However, due to the progression of NSTI confirmed in computed tomography scan, with increasing inflammatory markers and general deterioration with sepsis, the patient was transferred to our department, where he underwent surgical debridement with general care using antibiotics (ceftriaxone, ciprofloxacin, doxycycline), septic shock management and adjunctive HBOT. After 5 days of treatment in our department, where 10 HBOT sessions were performed, the general and local condition improved. Control cultures were negative and inflammation markers decreased: white blood cell (WBC) count from 13.93 G/L to 8.58 G/L; C-reactive protein (CRP) from 137.9 mg/L to 36.9 mg/dL, procalcitonin (PCT) from 8.52 ng/mL to 1.3 ng/mL. After this treatment, the patient was transported back to the referring unit for further treatment.

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Figure 1. A. Before hyperbaric oxygen therapy; **B.** After hyperbaric oxygen therapy

Although this clinical case was published as the first report of NSTI with *Vibrio vulnificus* originating from the Baltic Sea, it was not the first clinical case of Vibrio infection treated with HBOT in our department. In fact, we treated at least two similar cases of Vibrio infection also from the waters of the Baltic Sea.

In an earlier case from 2019, the disease occurred in a 60-year-old man admitted to the local general hospital with a purulent infection of the lower limb in the severe clinical condition of septic shock with multiorgan failure, cardiac arrest occurred during disease with successful cardiopulmonary resuscitation. *Vibrio cholerae* was identified in the wound tissue samples and this was confirmed by the independent governmental central laboratory using the polymerase chain reaction test. The source of the infection has never been documented, but according to information from the family, the patient with venous ulcerations of the lower limbs submerged in the waters of the central-southern part of the Baltic. Because of the clinical features of NSTI and the progress of the compartment syndrome, the patient was transferred to our department to extend the treatment with HBOT. General surgery, intensive therapy with mechanical ventilation, continuous veno-venous haemodiafiltration, antibiotics (ciprofloxacin, imipenem-cilastatin, linezolid), septic management, and adjunctive HBOT were used in the treatment. Within 5 days, 10 HBOT sessions were performed, resulting in improvement of the general condition and local tissues (Fig. 1A, B), resolution of septic shock, and reduction of inflammatory parameters: WBC from 22.19 G/L to 20.54 G/L; CRP from 264 mg/L to 65.1 mg/L; PCT from over 100 ng/mL to 3.16 ng/mL. After the end of HBOT, he was transferred to the referring hospital for further treatment.

We recently had yet another case of *Vibrio* NSTI from the Baltic Sea. In this case, the disease concerned a 39-year-old man who was admitted to our department from the west coast of Poland. No entry point for bacteria was identified, but the patient's history also revealed a bath in the southern waters of the Baltic Sea (at the western border of Poland). At the local hospital, he was treated for rhabdomyolysis of the lower limb with gas bubbles seen on radiographs. NSTI lesions progressed within a few days, requiring a fasciotomy. Severe septic shock developed with a multiple organ failure. In a microbiological study, *Vibrio vulnificus* was identified. The patient was transported to our department to add HBOT to surgical and intensive care treatment. During the 6-day stay in our department, 10 sessions of intensive care HBOT and multimodal treatment with surgical debridement, antibiotics (ceftriaxone, ciprofloxacin, doxycycline, linezolid, meropenem), septic shock management, and mechanical ventilation were used. There was an improvement both

Figure 2. A. Before hyperbaric oxygen therapy; **B.** After hyperbaric oxygen therapy

in general condition and at the wound site (Fig. 2A, B); septic shock resolved, and the inflammatory parameters decreased: WBC from max 16.07 G/L to 9.7 G/L; CRP from 296.8 mg/L to 91.6 mg/L; PCT from 50.9 ng/mL to 2.7 ng/mL. The clinical course of the disease was complicated by myocardial infarction. Due to the critical condition the non-invasive treatment was conducted. After HBOT treatment, a reduction in cardiac enzymes was also achieved: troponin from max 2.86 ng/mL to 0.57 ng/mL and creatine kinase myocardial bound (CKMB) from max 4.4 ng/mL to 0.5 ng/mL. After the end of HBOT, he was transferred to the referring hospital for further treatment.

All reported cases shared the common denominator of NSTI with severe clinical course. In all cases, empirical broad-spectrum antibiotic therapy, intensive care management adequate to the patient's condition, surgical interventions and adjunctive HBOT were used.

Hyperbaric oxygen therapy consists of breathing 100% at a pressure exceeding ambient pressure. In most cases, 2.4–2.8 ATA pressure for 60 to 120 minutes is used. For severe NSTI, hyperbaric sessions are performed initially every 8 hours in the first 24-hours and then every 12 hours for a total of approximately ten sessions [13]. In such doses, the influence of oxygen on bacteria and the patient's tissues, vessels, endothelium, cells, and enzymes, is multimodal. High oxygen tension in tissues generates reactive oxygen species (ROS) and reactive nitrogen species (RNS), which are critical mediators of cellular interaction, production of cytokines and growth factors, bactericidal effect on anaerobic bacteria with degradation of *Clostridium perfringens* exotoxins and modulation of leukocyte activation with enhancement of the killer function of neutrophils and their interaction with the endothelium [14]. It has been suggested that HBOT acts specifically against *Vibrio spp*, taking advantage of its more remarkable inability than other bacteria to tolerate ROS. When HBOT is combined with antibiotics, it exerts a bactericidal effect on *Vibrio spp* while it is only bacteriostatic to most of other bacteria [15–17].

The list of indications for HBOT is determined based on clinical evidence by the European Committee for Hyperbaric Medicine (ECHM), also approved by the European Underwater and Baromedical Society (EUBS) [18]. One of the indications for HBOT is an anaerobic and mixed bacterial infection, which is a general term also including NSTI. In patients with NSTI in severe clinical condition, i.e. septic shock, HBOT sessions should be carried according to the recommendations for hyperbaric intensive care [19].

The clinical cases presented here confirm the threat resulting from the presence of environmental bacteria, such as *Vibrio spp*, which, under optimal development conditions, may lead to NSTI and septic shock, with direct threat to health and life. Rapid diagnosis, empirical antibiotic therapy, decisive surgical procedure adequate to the wound severity and the possible addition of HBOT are the basis of the multimodal treatment.

Conflict of interest: None declared

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Healthy nutrition for seafarers during and after COVID-19 pandemic

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Recently the authors of this letter together with a multidisciplinary research team conducted a systematic review titled "Global overview of dietary outcomes and dietary intake assessment methods in the maritime settings" [1]. Our finding demonstrated high access to meat, processed meat and egg, frozen and canned food items, sugary drinks, alcohol, greasy and salty food among seafarers, while consumption of fruits, vegetables, dairy products, and cereals was lower than respective guidelines (e.g. Healthy Food Onboard Merchant Ships [1, 2].

Optimal nutrition strengthens the immune system and may reduce the risk and severity of coronavirus disease 2019 (COVID-19) [3]. Therefore, most studies have recommended high consumption of fruits, vegetables, whole grain foods, low-fat dairy products, and healthy fats (e.g. olive oil, fish oil) and limited intake of sugary drinks and high calorie and salty processed foods [3].

There are some studies that show a link between vitamin D deficiency and the COVID-19 risks and severity [4]. Moreover, optimal levels of vitamin D, A and C play a vital role for maintaining a well-functioning immune system [3]. Also, some nutrients like omega-3 polyunsaturated fatty acids have been associated with anti-inflammatory response and can increase resistance to upper respiratory tract infection [5]. So, adequate intake of such nutrients may favourably contribute to the prevention of or halt the progression to severe respiratory infections like COVID-19.

People who suffer from obesity, hypertension, cardiovascular disease, or diabetes often also have low vitamin D [3], and previous studies in the maritime settings have revealed that risk factors for non-communicable diseases including obesity, hypertension and metabolic syndrome are high among seafarers [6], which together with the often-unhealthy eating habits [1] may pose seafarers as a high-risk group for current health emergencies.

At the time of writing this letter, there were no special nutritional guidelines developed for seafarers during COVID-19 pandemic. Therefore, we call for a generation of new evidence-based dietary guidelines, especially for micronutrient supplementation, to this population group. Moreover, we invite shipping companies and authorities in maritime settings to support research in this field during and after COVID-19 pandemic. The results of such studies can contribute to the United Nations Sustainable Development Goals (Goal number 3: Good Health and Well-being) and improve the health of seafarers and inform similar future health emergencies.

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INFORMATION FOR AUTHORS

The International Maritime Health will publish original papers on medical and health problems of seafarers, fishermen, divers, dockers, shipyard workers and other maritime workers, as well as papers on tropical medicine, travel medicine, epidemiology, and other related topics.

Typical length of such a paper would be 2000–4000 words, not including tables, figures and references. Its construction should follow the usual pattern: abstract (structured abstract of no more than 300 words); key words; introduction; participants; materials; methods; results; discussion; and conclusions/key messages.

Case Reports will also be accepted, particularly of work-related diseases and accidents among maritime workers.

All papers will be peer-reviewed. The comments made by the reviewers will be sent to authors, and their criticism and proposed amendments should be taken into consideration by authors submitting revised texts.

Review articles on specific topics, exposures, preventive interventions, and on the national maritime health services will also be considered for publication. Their length will be from 1000 to 4000 words, including tables, figures and references.

Letters to the Editor discussing recently published articles, reporting research projects or informing about workshops will be accepted; they should not exceed 500 words of text and 5 references.

There also will be the section Chronicle, in which brief reports will be published on the international symposia and national meetings on maritime medicine and health, on tropical parasitology and epidemiology, on travel medicine and other subjects related to the health of seafarers and other maritime workers. Information will also be given on training activities in this field, and on international collaborative projects related to the above subjects.

All articles should be submitted to IMH electronically online at www.intmarhealth.pl where detailed instruction regarding submission process will be provided.

Only English texts will be accepted.

Manuscripts should be typed in double line spacing on numbered pages and conform to the usual requirements (Ref.: International Committee on Medical Journals Editors. Uniform Requirements for Manuscripts Submitted to Biomedical Journals, JAMA, 1997; 277: 927–934).

Only manuscripts that have not been published previously, and are not under consideration by another publisher, will be accepted.

Full texts of oral presentations at meetings (with abstracts printed in the conference materials) can be considered.

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