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Performance of survival equipment in cold climate conditions: laboratory and field tests of a desalination hand pump

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ABSTRACT

Increasing cruise tourism, fishing and offshore activity in a changing Arctic environment are challenged by severe climatic conditions. Maintaining safe operations is becoming more important. Access to fresh water is essential during an emergency evacuation and the following stay in lifeboats or life rafts. The required supply of fresh water adds extra weight to the survival equipment, and the stay at sea prior to rescue may be longer than the supply of water permits. In sufficiently low temperatures, the water supply may also freeze. In this case, a manual desalination pump might be a good supplement. However, the pump needs to be well-functioning at relevant temperatures, and measures must be taken to enable manual water production on a lifeboat or life raft in a stormy sea.

The present study focuses on a manually operated reverse osmosis pump, a SOLAS-approved emergency water supply source, particularly its performance in cold conditions. A controlled laboratory environment allowed testing of the pump's limitations with regard to water and ambient air temperatures. The production capacity declines significantly with lower seawater temperatures, reducing by half near the freezing point compared to 23 °C. Although not constant, the salinity of the produced water stayed within the recommended limits. In addition, the reverse osmosis pump was used as the source of drinking water during a survival and evacuation exercise lasting 36 hours. The field exercise allowed testing the pump in a modeled evacuation situation, and valuable feedback was received from the participants. Evaluation of the exercise revealed improvements and adaptations to consider for future use of the pump. Lab and field studies show why testing operational pump routines in the field and appliance limitations is crucial, particularly in cold climates.

KEY WORDS Emergency equipment; Desalination pump; Water supply; Cold Climate.

INTRODUCTION

As the ongoing climate change causes the Arctic to warm up, sea ice in the Arctic Ocean continues to retreat (Meier et al., 2021). This fact, combined with the growing demand for marine shipping and exploration of natural resources in the region, leads to a steady increase in ship traffic and other human activities (PAME (Protection of the Arctic Marine Environment), 2020). This, in turn, implies a necessity for well-thought safety measures aimed at reducing the risk and fatality of accidents and incidents in the sea. While striving for safety is a general trend, the Arctic poses additional challenges, such as vast territories, scarce population and harsh environments. Vessels suited for search and rescue (SAR) operations are few, and communication might be difficult. Time from evacuation to being rescued might be challenging and longer than expected, so in many cases, self-rescue is the only viable way to survive. These considerations make it crucial that survival equipment is functional in cold climates, applicable to arising challenges and safe to use.

Provisions of food rations and drinking water constitute an essential part of life-saving measures. While conserved food can be prepared and used relatively easily, sufficient volumes of drinking water add considerable weight to the safety equipment and might be difficult to store and protect from freezing. The IMO guidelines for LSA and arrangements recommend a minimum of 2 liters of freshwater per person per day for five days (International Maritime Organization (IMO), 2019). Investigation of the water supply onboard a lifeboat during winter revealed frozen waterbags, despite an activated cabin heater onboard. Frozen waterbags can be a challenge, particularly on electrical vessels.

In most offshore rescue operations, seawater is readily available, providing resources for freshwater production through desalination. Among various desalination methods, reverse osmosis offers a convenient design for a manually operated emergency desalinator. The ability to self-produce water is beneficial beyond the required time limit of five days. However, it has been shown in previous studies that survival equipment tends to underperform in harsh conditions (Solberg et al., 2016). Therefore, it is necessary to test the equipment in a relevant environment and improve its performance. In the case of a desalination pump, it is important to make sure that it is functional and able to produce the required amount and quality of drinking water from cold seawater. Figure 1 shows sea surface temperatures in the Arctic Ocean in March and September averaged over the last ten years (Merchant et al., 2019). In large areas, including shipping routes, seawater temperature is below 5 °C.

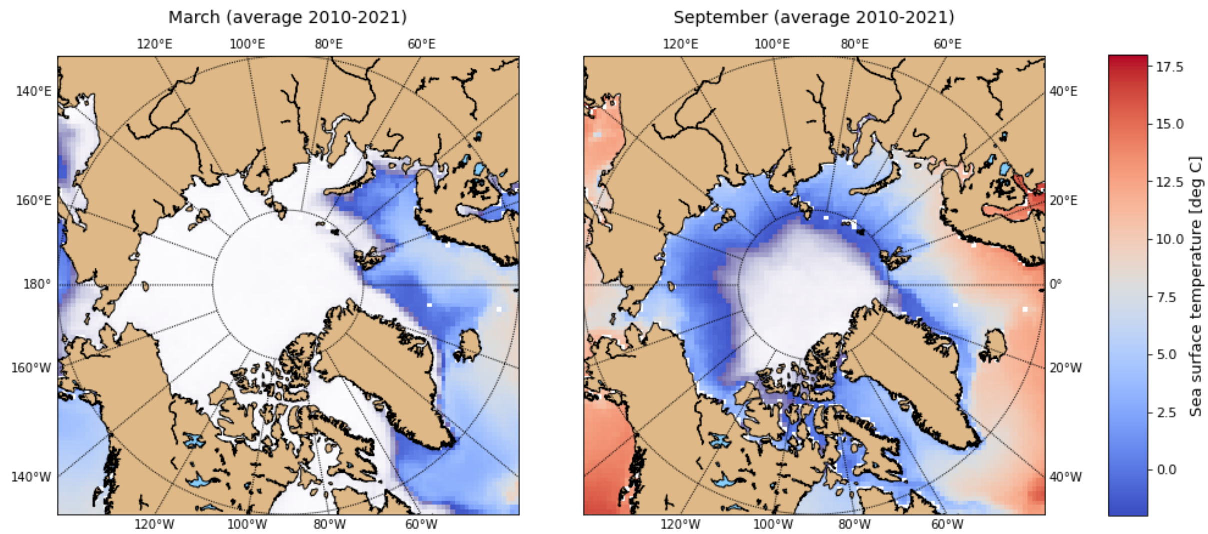

Figure 1. Satellite-based sea surface temperatures in the Arctic Ocean in March and September (averaged over the last ten years) (Merchant et al., 2019).

The present study is a follow-up on (Engtrø & Sæterdal, 2021) and aims to evaluate the performance of a manually operated reverse osmosis pump Katadyn Survivor 35, which is a SOLAS-approved source of emergency water supply (Katadyn, n.d.), both in laboratory conditions and in an outdoor emergency simulation. The lab experiments provide a controlled environment, allowing for a series of pumping tests with different temperatures of source seawater, and the field test helps to reveal shortcomings of using the pump in an emergency and evaluate improvements. Combined, the two parts of the study provide a thorough review of the chosen pump model as a piece of emergency equipment designed for the Arctic climate.

DATA AND METHODS

Desalination pump

The desalination pump tested in this study was a manually operated Katadyn Survivor-35 LL device, which is approved by SOLAS as an emergency water source at sea. The device is specified to produce 4.5 liters of fresh water per hour ± 15 %, with an average salt rejection of 98.4 % and a minimum of 96.8 % (Katadyn, n.d.). Its operation principle relies on reverse osmosis, i.e., forcing seawater through a semipermeable membrane under added pressure so that salt molecules do not pass through the membrane while fresh water does. The necessary pressure is created by the pump operator pushing and pulling the lever. The pump is equipped with three hoses: source seawater intake, freshwater output and brine output. The intake hose is protected with a cylindrical filter to prevent unwanted particles from entering the pump. Different pump versions also have different lengths of intake and wastewater hoses. The pump system and scheme of its operation principle are shown in Figure 2 a and b, respectively. Note that the picture shows a pump version with shorter intake and wastewater hoses than the one used in the experiments.

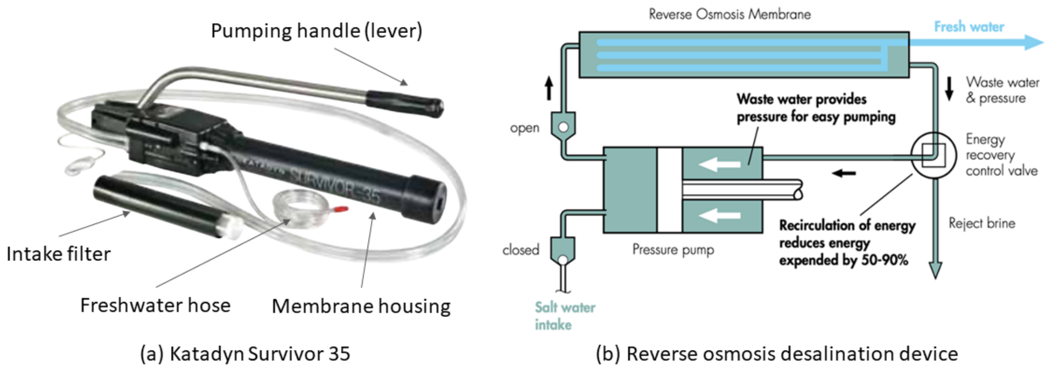

Figure 2. Katadyn Survivor 35 pump to the left and reverse osmosis process to the right, pictures taken from (Katadyn, n.d.)

Laboratory instrumentation and setup

Laboratory tests are designed to establish a controlled environment where the desalinator functionality can be tested to its limits and closely monitored in various conditions, which is challenging to perform in the field. The main variable parameter is the temperature of the source water, with the aim of evaluating quantity, per unit time, and quality of drinking water produced by the desalinator. The cold lab at The Arctic University of Norway in Narvik operates in the temperature range of -30 to 10 °C and regulates the set temperature in cycles with an amplitude of about 0.5 °C.

The seawater was sourced simultaneously in the Ofotfjord, ensuring a similar baseline of seawater properties. The samples were stored in closed containers to prevent evaporation and contamination. Prior to testing, the seawater was stored in the lab until the acquired test temperature was stable.

Ambient air and seawater temperatures were logged with a Hioki LR8400-20 at one-second intervals throughout the test with T–thermocouples. During testing, the ambient air and seawater temperatures were approximately equal. The produced water was collected and weighed with a Kern DS 16 K0.1 scale. The salinity of seawater and processed water was measured with a Hanna HI98192 salinity meter.

The instructions for the reverse osmosis pump detail how to use the device. The pressure indicating rod is extended to indicate adequate pressure or pump frequency, and overexertion leads to leaking from the indicator rod. The working frequency has to be adjusted based on the seawater temperature, as experienced in the previous study (Engtrø & Sæterdal, 2021). In addition, the water produced with the first 60 pumps is supposed to be discarded due to higher salinity. To adhere to these instructions, the first produced water was cast out with the wastewater, and prior to the test, a rhythm was found by using a metronome to determine the maximum working frequency. One cycle was completed when the lever was worked up and down, and the corresponding frequency was measured in bpm. A metronome was used for a consistent pumping rhythm throughout the test period of 30 minutes. Additionally, the input and wastewater hoses were separated to avoid mixing brine with the source water.

Field-test instrumentation and setup

A field test was included in the study to evaluate how people without pre-existing knowledge about the product manage to use the pump in a simulated emergency over a prolonged time. In addition, the exercise was used to assess related issues arising from the specific lifeboat environment, such as access to seawater through an open hatch and other technical challenges that would not be revealed without a field test. The field test of the desalination pump was performed during the SAMF, SARex Arktisk Maritim Folkehelse, survival and evacuation exercise carried out in Beisfjord, Norway, 7th to the 8th of October 2022. The main objective of the exercise was to document and evaluate emergency equipment and rations in accordance with the IMO Polar Code (International Maritime Organization, 2016) to offer improvements and insights to increase safety at sea. The exercise lasted for 36 hours with a limited amount of equipment and rations. The participants were divided into two major groups, and one of them was stationed on a Viking Norsafe Miriam lifeboat, see Figure 3, for the duration of the exercise.

Figure 3. Inside the lifeboat, hatches that needed to be opened during pumping are shown.

The five volunteers in the lifeboat were mainly students from the Arctic University of Norway, a young and healthy group of people. No guidance was given on using the pump apart from the manufacturer's instructions. Since the objective was to test the applicability and functionality of the desalination pump by measuring the quality and quantity of the desalinated water, the participants drank an amount of store-bought water equal to what they had produced. The processed water was collected into a 0.5 l receiving bottle, which was connected to the freshwater hose of the pump and emptied into a 20 l container every time the bottle was full. The containers were changed every 6 hours.

The exercise was documented with several GoPro cameras inside the lifeboat and observations by the crew present to ensure safety and perform measurements. Throughout the field test, the lifeboat's indoor temperature and relative humidity were monitored with a Fluke 54II thermometer and a VelociCalc 9565. The outdoor climate with wind speed, temperature and relative humidity was logged with a weather station, Aanderaa Smartguard basic w/ SR10/VR22, mounted on top of the lifeboat steering tower. Seawater samples were collected twice during the 36 hours, and seawater temperature was measured. The weight and salinity of the produced freshwater was measured as described in the lab section. After the exercise, the participants' experiences were collected in a focus group interview.

RESULTS FROM LABORATORY AND FIELD TESTS

Laboratory testing

Figure 4 and Table 1, summarize the results obtained in the cold climate laboratory experiments in 2021 and 2022. In both years, the amount of fresh water produced by the pump follows a clear downward trend with decreasing temperature. At the lowest temperature, the production rate dropped by more than half compared to 23 °C. A noticeable drop from the general trend is observed between 3 and 7 °C, which may be related to the fact that the density of freshwater peaks at about 4 °C, making it more difficult for water to pass through the membrane. According to the technical specifications the pump produces 4.5 liters of fresh water per hour ± 15 %, which translates to a minimum of 3.8 liters per hour. Production rates at seawater temperatures of approximately 7.5 °C and lower did not fulfill the manufactures specification.

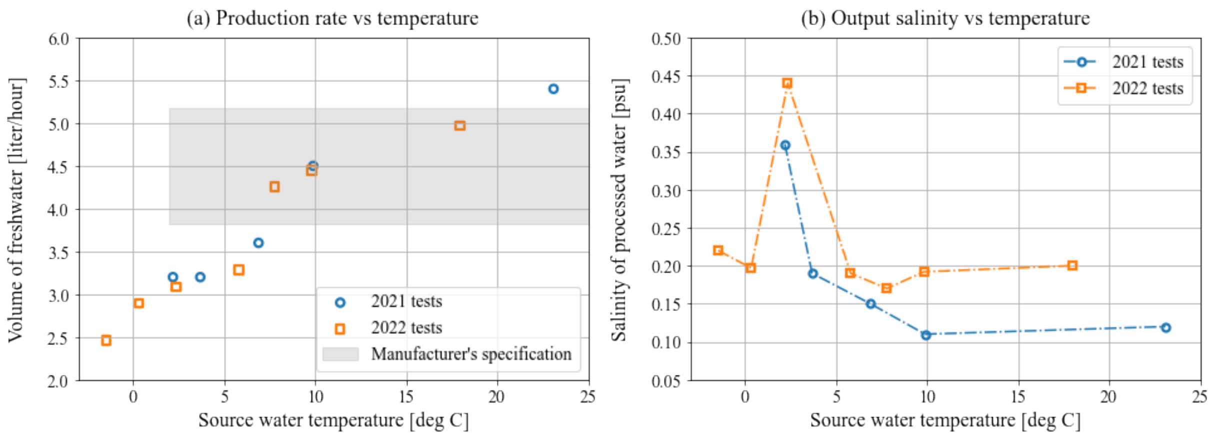

Figure 4. Graphic presentation of results: production rate and salinity vs temperature.

The salinity of the produced water shows a sharp increase between 1 and 4 °C, reaching above 0.4 psu, but stays below 0.25 psu for other tested temperatures. Such behavior might be partly attributed to the density maximum as the most prominent feature of water at near-zero temperatures. This study complements the previous one in showing that the salinity of produced water has a peak rather than increases monotonously with decreasing temperature.

The salinity of the produced water measured in the 2021 tests was noticeably lower than that in the 2022 tests. This is most likely due to the differences in the operation procedure: in 2021 a single operator performed the pumping for one hour with no pauses, in 2022 two operators pumped for 30 minutes in 10 and 5-minute shifts (10-10-5-5). The inner structure of the pump suggests that even short pauses needed to change the operator might lead to additional salt diffusion, resulting in higher overall salinity of the produced water. It was also proved through a small test that the first 0.4 liters of produced freshwater after the pump had been stored at room temperature for about 1 hour had a salinity of 1.34 psu, thus exceeding the WHO standards for drinking water of 1.0 ppt (World Health Organization (WHO), 2022). At the beginning of all tests in the lab, the first produced water was discarded.

The source seawater salinity was 24.0 psu in 2022, and 26.8 psu in 2021, which is lower than the average ocean salinity of 35 psu (Jain, 2011). The desalinator's salt rejection ability is dependent on the initial level of salt (Engtrø & Sæterdal, 2021). If source water has higher salinity, the output water may have salinity values above the limits around 3 °C.

The volume trend indicates that the regulations of seawater desalination as an emergency drinking water source should be subject to careful consideration when applied to cold seas, taking into account the reduced amount of freshwater that can be produced with this method.

Table 1 Laboratory results 2022

Source water temperature [deg C]	-1.46	0.35	2.36	5.82	7.81	9.83	17.97
Volume of freshwater [l/h]	2.46	2.90	3.08	3.28	4.26	4.45	4.97
Salinity of freshwater [psu]	0.22	0.20	0.44	0.19	0.17	0.19	0.20
Pumping frequency [bpm]	17.5	20	20	20	25	30	30

Laboratory: sub-zero and cold storage tests

The desalination pump is designed to work with source water temperatures between 2 and 45 °C (Katadyn, n.d.). However, as can be seen in Figure 1, in close proximity to sea ice the temperature of seawater can fall below zero, i.e., near the freezing point of saline water. Several tests were run to assess the pump's performance below the lower limit. At ambient air and water temperature of about -1.7 °C and -1.2 °C the pump malfunctioned. In higher air temperatures, with a seawater temperature of approximately -1.5 °C, and a pump frequency of 17.5 bpm, the pump produced drinking water at a rate of 2.5 liters per hour. Additional experiments were run aiming to test the ability of the pump to produce freshwater after being stored at -20 °C for approximately 36 hours. The test resulted in pump failure for the device stored without preserving liquid. The booklet of the pump gives instructions on storage, but no such information is on the card attached to the pump. The booklet warns that the strainer can clog due to unusually cold or salty water (Katadyn, n.d.).

Field testing

Five people shared one pump and produced in total 16.4 liters of drinkable fresh water during the field exercise and thereby exceeding the organizer's prescribed amount of 2 liters per day.

The group was introduced to the pump procedure approximately four hours into the evacuation exercise and stayed engaged throughout the test. The group planned their water consumption during the night and pumped enough before going to sleep. Toward the end of the exercise, the participants were determined to reach the goal of 3 liters each and pumped enough for the remaining time. They did not strictly follow the instruction of pumping 0.5 liters before drinking 0.5 liters. Still, they produced more water with the pump than the 11.1 liters they drank during the 36 hours. Accounting for one participant who pulled out after approximately 24 hours, the group should have consumed 14 liters.

After the field exercise, the subjects participated in a focus group interview. During the interview, they shared that using the pump had not been taxing and ascertained that they could have continued pumping for five days. The instruction card on the pump was easy to understand, but the illustration could have been more instructive, as the written instruction was only in English. The group also suggested improvements such as brackets or alternatives to lock the pump into a fixed position to ease pumping. In addition, the group was mindful that the outdoor temperature during the exercise could have been lower and suggested a separate hatch to lead the hose to water. Opening the doors could let out too much heat.

The group tasted the produced water and reported a salty taste. The tasting was done of the first water produced by the pump after a period when the pump had been inactive. As tested in the lab, the first water contains salt levels above recommended levels, and the first water should therefore be thrown away. One participant had tasted the produced water during a pumping operation and had not detected the same salty flavor.

Water was not foremost on anyone's mind at the start of the field test. When evacuation procedures and other events were done, and the group was introduced to the task of producing their drinking water, they had already spent more than four hours without liquid. The instruction of pumping before drinking was set aside for the first bottle of water to avoid compromising the participants' well-being. This experience shows one of the shortcomings of having the pump as the main or only source of drinking water, a point also discussed during the focus group interview. In an emergency situation, the first hours after an evacuation can be occupied with searching for survivors, tending to injuries, communicating with search and rescue and other lifeboats, navigation, familiarizing with the vessel, and caring for and calming passengers. Stressed situations could also increase dehydration. The first hours are expected to be stressful and starting the water-producing process can be neglected. In a crowded lifeboat, the production time could become a bottleneck, even with multiple devices.

In conclusion, the group had a positive attitude towards making their own supply of drinking water; they said that producing drinking water was the only task that made sense during the stay in the lifeboat.

Throughout the field exercise, the participants experienced relatively good conditions. The lifeboat is designed for 55 people, leaving the group of five with ample space for moving and stretching, compared to the situation in a filled lifeboat. The average indoor temperature was approximately 16 °C, varying between 12 and 22 °C, and the indoor relative humidity varied between 45 and 65 %. The outdoor weather was cool but not sub-zero with temperatures ranging from 5.6 to 11.5 °C and wind speeds from 0 to 8.7 m/s, with average values of 8.1 °C and 2.6 m/s. The low wind speed resulted in a calm sea state, and no one reported seasickness. Other benefits during the stay in the lifeboat that could be emphasized are that the group had indoor lighting at their disposal and that this particular test boat was equipped with a toilet, which is not usually found in lifeboats. The group did not report being hungry or thirsty, indicating that, although the rations were monotonous, they did not lack nutrition or fluids. The absence of seasickness, cold, injuries and other limiting factors favorably impacted the group's ability to work for their drinking water. The possibility of less optimal conditions is an argument towards not having the pump as the only source of water onboard.

As discussed briefly, the pump's access to seawater was not optimal. The group raised concerns about the indoor temperature if the door needed to remain open in lower temperatures. Even with the outdoor climate experienced during the test, maintaining a comfortable indoor temperature could be difficult if the pump had been operating continuously to serve more people. And in lower temperatures, the situation could be severe. In addition to temperature, opening the hatches for the pump would be difficult during high waves, as seawater could enter through. Alternative solutions are, for instance, separate seawater access for exiting the hose or an indoor bottom hatch. The version of the pump used during these experiments has an elongated hose of 4.45 meters compared to the original version of about 1.5 meters. If the original version of the pump had been used, the hose would not have reached the sea surface. The pump is targeted for use on rafts, and adjustments are needed to both lifeboat and the pump for the solution to work optimally on board.

88 % of the water production process was reviewed by examining video recordings from the

exercise. The remaining production time is assumed to be equal to the value averaged from this sample. Based on the weight of produced freshwater, one extra liter was added to the overall production, but the person pumping could not be identified, and identity X is assigned to this liter in Table 2.

Seawater samples were collected close to the lifeboat with a salinity of 19.7 psu on Friday, and 25.4 psu on Saturday, the seawater temperatures were 7.4 and 8.2 respectively. Based on the experiments in the lab with sea temperatures of about 7 – 8 °C, one would expect a production rate above 4 liters per hour, and output salinity below 0.2 psu.

The average production rate computed from the observed time and measured weight was 3.44 liters per hour. Several factors can explain the difference from laboratory conditions. While pumping in the lab, the pump was locked in place, and a metronome was used to keep the optimal beat. In the boat, participants had several small pauses that could reduce the pressure build-up in the pump. Some pauses were due to changes in the position of the body and the pump, change of operator, and minor breaks while talking or other distractions. Pauses longer than 15 seconds were not counted as pumping time. Most 0.5 liter portions were produced without pause, but on some occasions, the operation was abandoned and continued 15-30 minutes later, allowing salt levels in the pump to increase. The lever was not fully extended during pumping, as many operators for instance held the pump under their thigh to prevent it from moving. The group occasionally overexerted the pump, causing the pressure valve to release liquid. Instead of reducing the frequency, as described on the instruction card, the group attached a bottle to capture the spraying water from the pressure rod. The reduced production rate compared to the lab experiments had been expected and needs to be accounted for when evaluating the number of people the pump can supply.

Based on the time spent producing water, it is evident that everyone participated, but some people worked more on the water production task. “A” took charge, read the instructions, produced the first bottle of water, and helped others whenever there was a problem. “A” also instructed while using the pump for the first time that pumping should be performed evenly and that the pressure indicator rod would leak if overworked. Throughout the exercise, all participants initiated and volunteered to pump, and the work distribution with time can be seen in Table 2 and Figure 5.

Table 2. Drinking water production and time spent pumping by individual participants.

ID	A	B	C	D	E	X	SUM/AVG
Water produced	1.5	4.8	5.1	3.0	1.2	1.0	16.5
Duration [min]	27	80	86	56	21	17	287
Production rate [L/h]	3.3	3.6	3.6	3.2	3.3	3.5	3.45

Six intervals for replacing the fresh water containers were chosen prior to the exercise, changing containers at 05:00 and 11:00 am and pm. During two of the intervals, no water was produced: from 23:00 Friday to 05:00 Saturday and after 17:00 Saturday. The intervals allow for comparison of the amount produced with video observations and investigation of the measured salinity. Based on the weighted result, one extra liter of produced water was added for Friday evening. There was downtime on the camera between 21:42 and 23:10, and pumping could have been performed in this interval. Alternatively, someone could have added an extra liter of fresh bottled water to the water collector between 17:00 and 23:00. This time interval has the lowest salinity, see Figure 5.

The seawater salinity was measured at 19.7 psu on Friday and 25.4 psu on Saturday. The discrepancy could be due to the first sample being collected from the top layer of the sea surface

(0-5 cm), where salinity was lower because of rainfall and river discharge, while the second sample was taken with a bucket reaching down ca. 50 cm below the surface. In the lab experiments, 24.0 psu was measured in the source water. The previous study, (Engtrø & Sæterdal, 2021), indicates that lower source water salinity results in lower salinity in the processed water. However, the relatively high salinity from water pumped on the boat cannot be explained by a difference in source water levels. Lab tests in the equivalent temperature range showed a maximum salinity of produced freshwater as 0.19 psu, while in the field test salinity ranged from 0.35 to 0.69 psu.

Despite the group reporting that the instruction was easy to read, no one was observed throwing away the first 60 pumping strokes when the device had been inactive. This practice likely influenced the water quality, as discussed previously. The highest salinity was also found at the first interval of each day, containers 1 and 3, when the pump had been stored for several hours. Figure 5 shows pumping work done by participants A-E on the timeline, with the production rate illustrated by the column height.

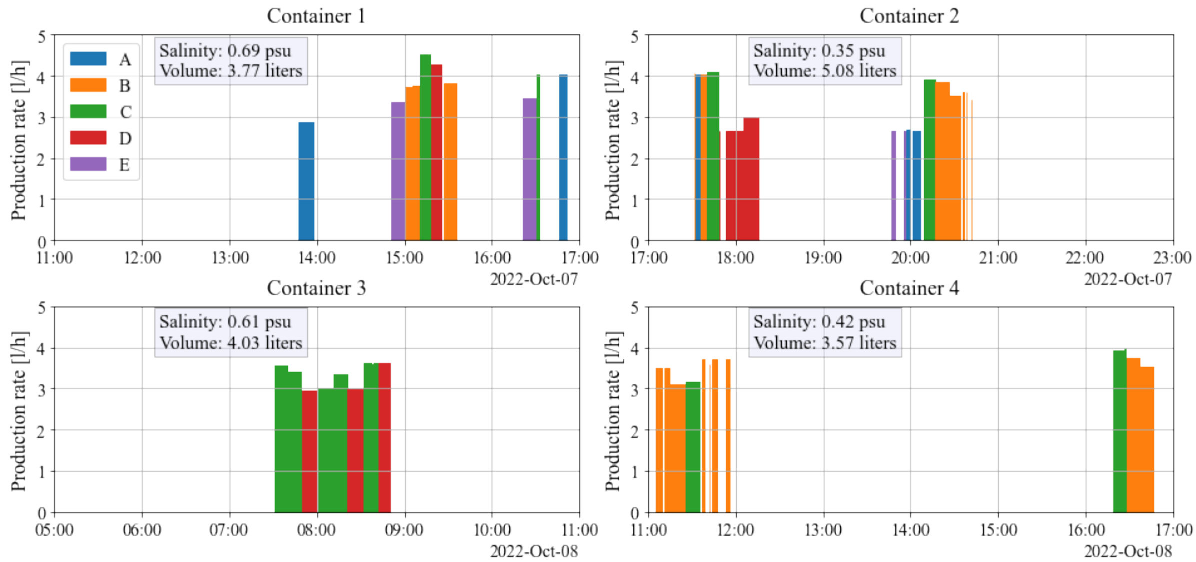

Figure 5. Production of drinking water by the participants on a timeline divided into four controlled intervals.

Collection of rainwater

As an additional source of drinking water, the group installed the rain collector on the roof and collected a total of 1.7 liters of rainwater between approximately 12:00 to 19:30 Saturday. The size of the rain tarp is one square meter and standard accessory in lifeboats (ISO (International Organization for Standardization), 2022). In the same time interval, the Norwegian meteorological institute reported a total of 6.8 l/m^2 rainfall. The distance of approximately 9 km from the meteorological station to the test site results in large margins of error, in addition to other factors such as rainwater lingering on the tarp and in the tubing. The salinity was measured at 0.03 psu.

CONCLUSIONS AND RECOMMENDATIONS

In cold climates, survival equipment may underperform or malfunction due to environmental conditions, cold effects on materials and human errors. Therefore, it becomes crucial that life-saving equipment is user-friendly and applicable in cold conditions. The present study of the Katadyn 35 Survivor reverse osmosis pump for emergency drinking water concurs with our study from 2021, but by expanding the temperature range and adding a field test, new information is brought to light.

The laboratory experiments indicate that the reverse osmosis pump exhibits a lower production rate than cited by the manufacturer when the temperature of source water is below 7.5 °C, and production is halved in sub-zero temperatures. In all the tests the salinity values stayed within the recommended limits for drinking water, despite a peak at around 3 °C. It was also discovered that both storing the pump at sub-zero temperatures and using icy water as a production source could cause malfunction, which may be attributed to ice particles entering the pump and/or water freezing inside the pump due to supercooling, which is consistent with the pump instructions.

The field test revealed a reduced production rate of approximately 14% compared to the lab experiments conducted at similar temperatures of source water. The decreased production was likely due to the participants' pump operation techniques, caused both by minor breaks and a lack of knowledge on how to operate the pump. Still, the device allowed the participants to produce the required amount of drinking water. In addition, in the aftermath interview, the participants shared valuable insights and suggested improvements for optimizing the use of the pump in the lifeboat, for instance, easy access for the hose to seawater, options for utilizing the vessel's power to drive the pump, and brackets to secure the pump.

The salinity of the processed water was found to be higher in the field test, between 0.35 and 0.69 psu, compared to the lab experiments, where the maximum value was 0.19 psu. The discrepancy is likely due to partially disregarding the manufacturer's instructions, with pauses in operation and failure to discard the first processed water. Still, the measured values were within the recommended limits for drinking water, and within the pump specifications of minimum salt rejection of 96.8%.

Due to the salinity peak at seawater temperature of 2-4 °C, the pump should be tested with higher source salinity, to ensure that the salinity remains within the recommended limits at these temperatures.

The test group from the survival exercise commented that producing their own drinking water was a meaningful task, that helped to avoid monotony and inactivity, and the group did not find the task strenuous. However, the conditions of the experiment were overall mild, both in terms of weather and amount of people onboard. Under less favorable circumstances, a lower production rate needs to be taken into account. A follow-up field study in more challenging conditions could provide additional data.

Main conclusion: The Katadyn 35 Survivor reverse osmosis pump for emergency drinking water was tested from 18 °C to the freezing temperature of seawater. All produced water was drinkable, however, at seawater temperatures below 7.5 °C, the prescribed production rate cannot be maintained, and ice water can cause malfunction. In the field, in sub-optimal conditions, the production rate will be lowered by at least 14 %. When outfitting a vessel with a pump, an evaluation of the coexistence should be performed for optimization and safety. A device cannot be the sole source of emergency drinking water.

Further work could include testing the pump with seawater temperatures of 2-4 °C and salinity at 35 psu, and modifications to the lifeboat to accommodate the emergency water supply pump.

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