TEST OF HERDER AND CONTROLLED BURNING OF SPILLED OIL IN KAZAKHSTAN

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ABSTRACT

Recent years have seen renewed interest in the viability of using herding chemicals in conjunction with in-situ burning. NCOC, an operator in the shallow north Caspian Sea, undertook herder research as an extension to studies performed under the Arctic Response Technology Joint Industry Programme (JIP). The purpose was to investigate the feasibility of using herders as part of their response toolkit.

Laboratory tests were performed in Kazakhstan on weathered Kashagan export crude oil, using two herders listed on the US NCP Product Schedule. Results were positive and it was considered that a reasonable size test spill under realistic conditions was required to verify laboratory work.

In November 2018 a field trial was undertaken in the boat basin at Damba in western Kazakhstan. A volume of 400 litres of artificially weathered Kashagan crude was pumped onto the water surface and allowed to spread. Air and water temperatures were just above freezing and a small amount of ice was present due to overnight low temperatures. The test was recorded by an unmanned aerial vehicle, using thermal IR and 4K video.

After the oil had been allowed to spread out to be <1 mm, i.e. too thin to sustain combustion, a small boat was used to spray Siltech OP-40 herder around the periphery of the oil. After less than five minutes the effect of the herder became apparent. The oiled area was observed to begin contracting. A member of the boat crew successfully placed an igniter into the thick oil. A plume of black smoke was produced and the oil burned vigorously with flames of 2 to 3 metres high for approximately 8 minutes. After the burning had finished a visual inspection showed a relatively small quantity of oil residue. Pre- and post-environmental monitoring of the test site was undertaken.

Based on the success of the test, the next steps are to develop a formal methodology for the inclusion of herders in the list of approved oil spill treatment products. It will then be possible to incorporate the technique into contingency plans using NEBA/SIMA justification. This will have the potential to improve the response options and speed of response to incidents in broken ice or open waters.

INTRODUCTION

The use of herders as a tool for on water oil spill response has been the subject of renewed interest and various research interest in the past 15 years (Arctic Response Technology JIP, 2015). The principle of herders is to thicken free floating oil slicks that have spread too thinly (<3 mm) to support combustion. This is accomplished by spraying a small amount of herder containing surfactant around the perimeter of the slick. The surfactants will spread to ultimately form a monomolecular layer that significantly reduces the surface tension of the water. The reduced water surface tension reverses the oil spreading tendency and a thin slick can rapidly re-thicken. Herded slicks may be ignited and removed from the surface through controlled in-situ burning.

Kazakhstan has developed its national oil spill response framework (Amanzholova, 2017), including regulations for the approval of dispersant products and the use of in-situ burning. The authorities remain open to consider the potential use of all oil spill response tools. This includes additional oil spill treatment agents such as herders, subject to proper regulation and net environmental benefit analysis, NEBA or spill impact mitigation assessment, SIMA (IPIECA-API-IOGP, 2017).

NCOC (North Caspian Operating Company N.V.) is the operator of the North Caspian Project that includes five offshore fields including Kashagan. NCOC participated in the Arctic Response Technology JIP (http://arcticresponse.wpengine.com/) that included herder studies. They recognized that incorporating herding and burning within their overall contingency planning could strengthen oil spill preparedness. This included possible use in broken ice conditions.

Oil spill response in the northern Caspian Sea faces several challenges. Conditions can be harsh with an air temperature variation from −35°C in winter to +40 °C in summer. The water in the northern Caspian Sea is very shallow (average depth of 4–6 metres), is brackish (<10 psu) and freezes in winter. These conditions can impose challenges to oil spill response techniques such as mechanical containment and recovery and the use of dispersants.

NCOC decided to extend the work of the Arctic Response Technology JIP and further investigate the feasibility of using herders in combination with controlled in-situ burning (ISB) in Kazakhstan. Previous field trials were acknowledged (Buist, 2010 and Singsaas et al, 2017) but it was considered important to undertake testing with a local oil that could be observed by relevant authorities in Kazakhstan.

NCOC commissioned herder laboratory studies on the Kashagan oil produced from their operations and then undertook a field trial using the herd and burn technique.

LABORATORY STUDIES

NCOC worked on this project with KazMunayGas (KMG) Systems & Services and the KazMunayGas (KMG) Scientific Research Institute of Production and Drilling Technology, who tasked the chemical department of the E.A. Buketov Karaganda State University to conduct a series of laboratory studies. Through 2017 and 2018 the laboratory tests were performed on weathered Kashagan export crude oil, using two herders listed on the US NCP Product Schedule i.e. ThickSlick 6535 and Siltech OP-40, kindly supplied by DESMI-AFTI.

The testing focussed on characterizing the oil's properties and the effectiveness of the herders using a bench-scale (1 m^2) test pan. Temperature and salinity were varied through the series of tests. Tests were performed at water temperatures of 5°C (± 2°C) and 15 C (± 2°C) to represent variation in seasonal temperatures in the north Caspian Sea.

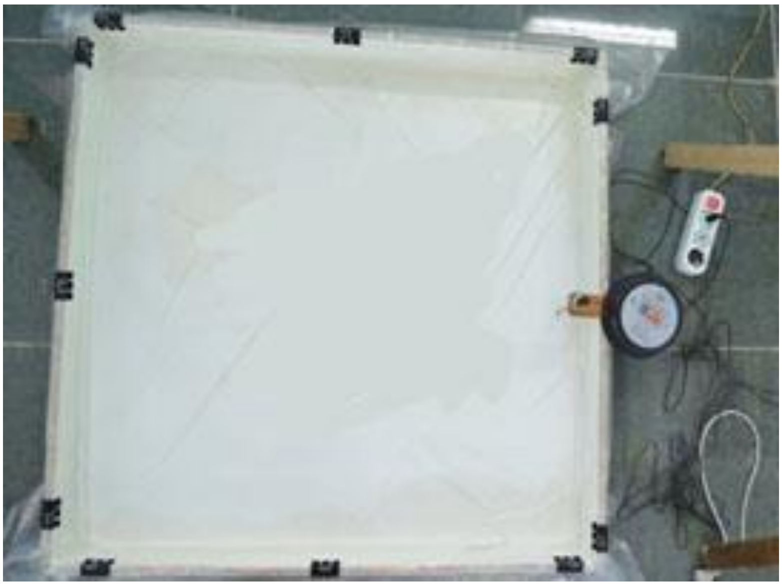


Figure 1 — Pan used for laboratory tests

Method

The test water was prepared using sea salt with a salinity of 6 ‰, 12 ‰, 18 ‰.

Test materials:

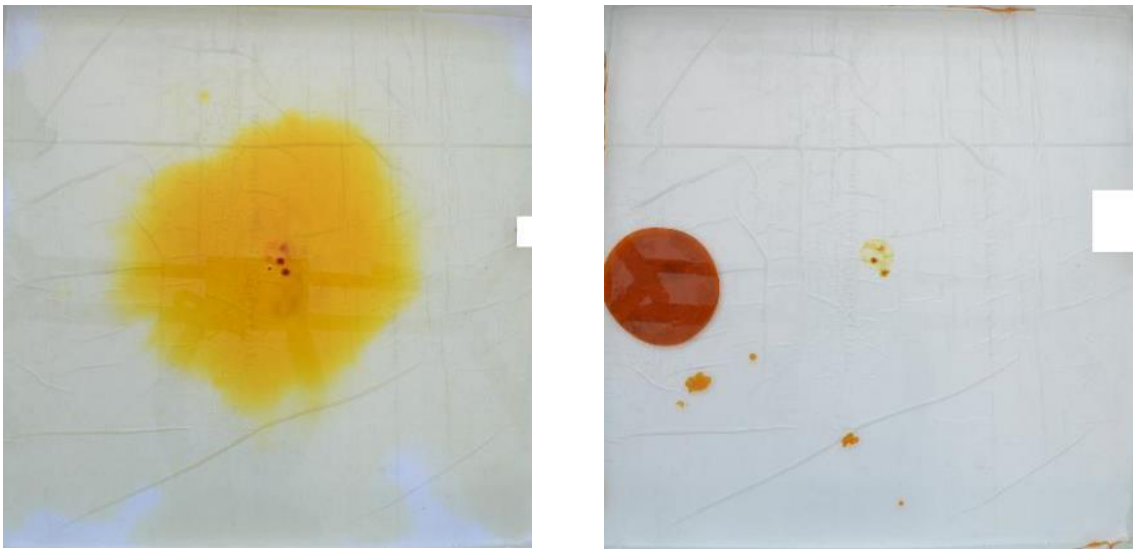
- Volume of water with the conrolled salinity - 20 L
- Oil volume - 100 mL (oil weight was accurately measured by weighing a cylinder with oil and the empty cylinder to estimate the weight by difference and correct volume by density). Studies were performed on Kashagan oil processed under different conditions:
  - Kasagan oil weathered at 60 °C (oil density = 0.822 g/mL)
  - Kashagan oil stripped at 200 °C (oil density = 0.856 g/mL).
- Herder volume - 150 µL (dosing by means of micropipettes; as with oil, herder weight was estimated by difference between weights of a full and empty micropipettes, and volume by density).

For each test, the pool was covered with a freshly washed brand-new plastic film fastened with large clips. Water was poured into the pool and brought to the appropriate temperature; 100 mL of oil was added and allowed to spread over the pool surface; 150 µL of herder was then added at the edges.

Slick behaviour was observed using a digital video camera and digital still-shot camera. The pictures were analysed using a PC (Photoshop application, and Python-language application for calculation of tinted slick areas). The contraction of the slick area could be converted into an average thickness increases, due to known oil volume.

Results

Kashagan crude oil is brown orange in appearance, as can be seen from the example photographs shown in Figure 2.



OP-40 herder, Kashagan oil weathered at 200 °C on 15 °C water (6 ‰)

Before herder application (left) 5 minutes after herder application (right)

Figure 2. Example of oil appearance before and after herding

An extensive series of tests were performed, with example results shown in Figures 3 to 5. Initial testing identified that salinity did not affect herder effectiveness and therefore most of the testing was performed at 6 ‰, reflecting typical conditions in the north Caspian Sea.

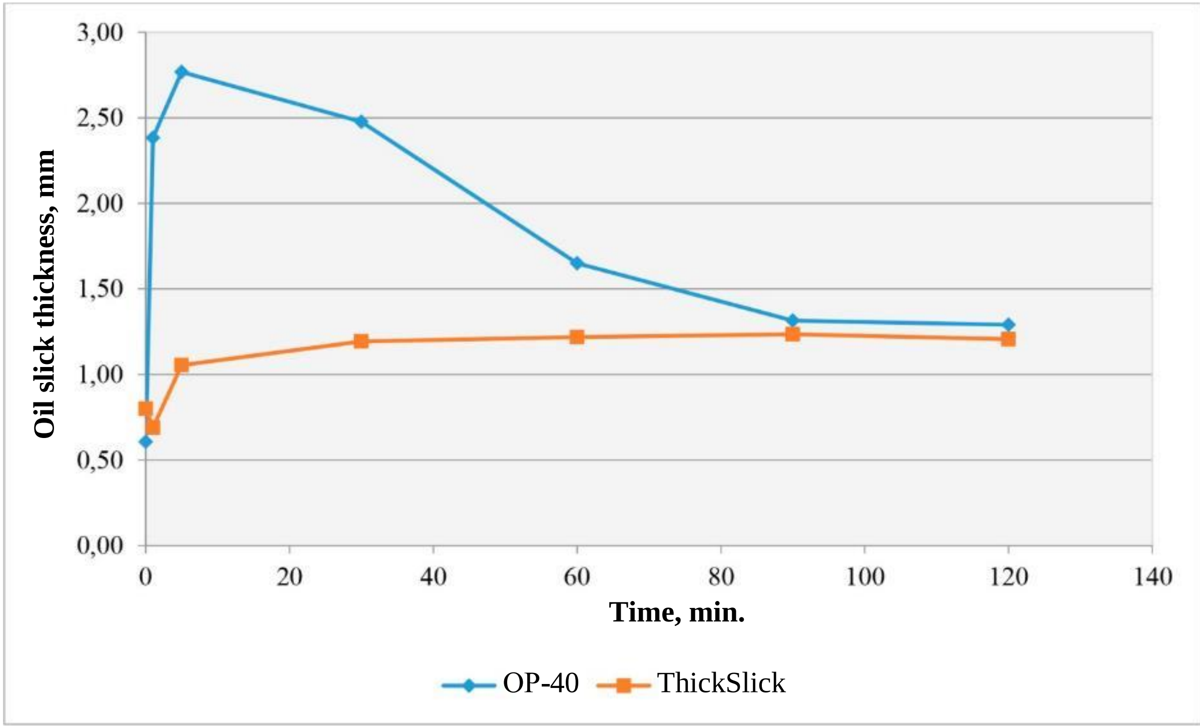


Figure 3. Herder effectiveness - Kashagan oil weathered at 60 °C on 6 ‰ 15 °C water

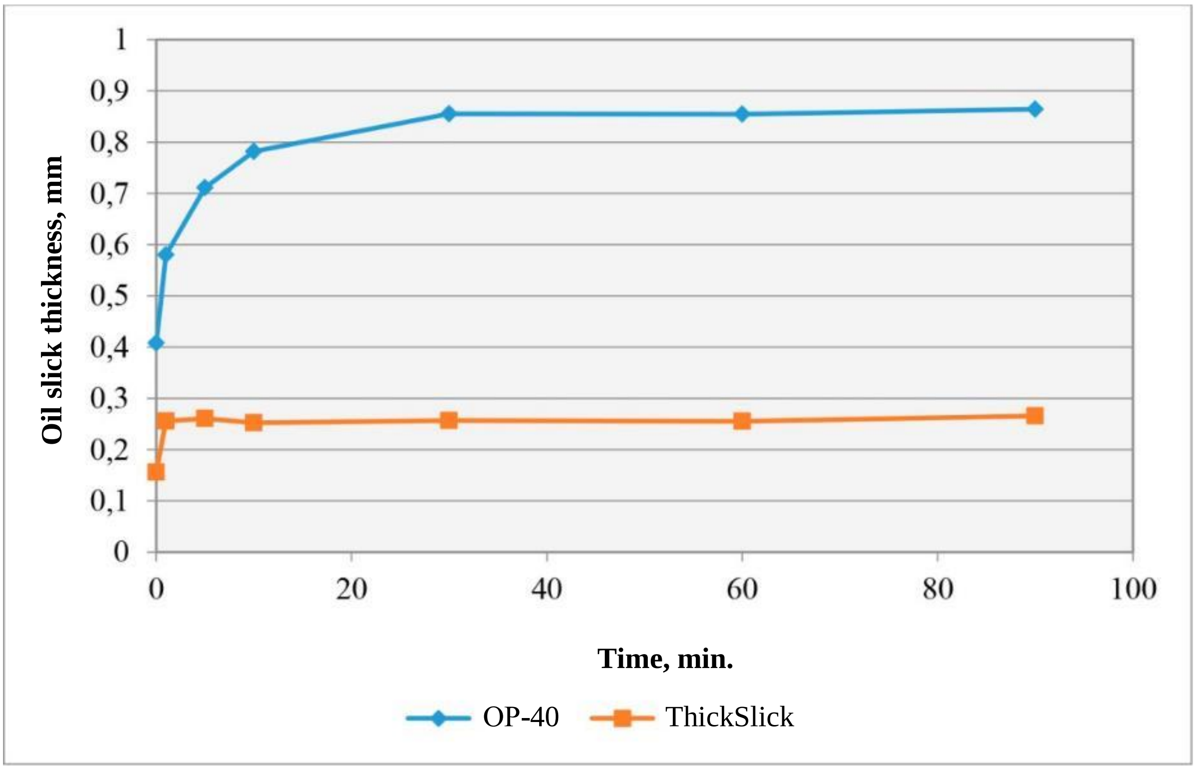


Figure 4. Herder effectiveness - Kashagan oil weathered at 200 °C on 6 ‰ 5 °C water

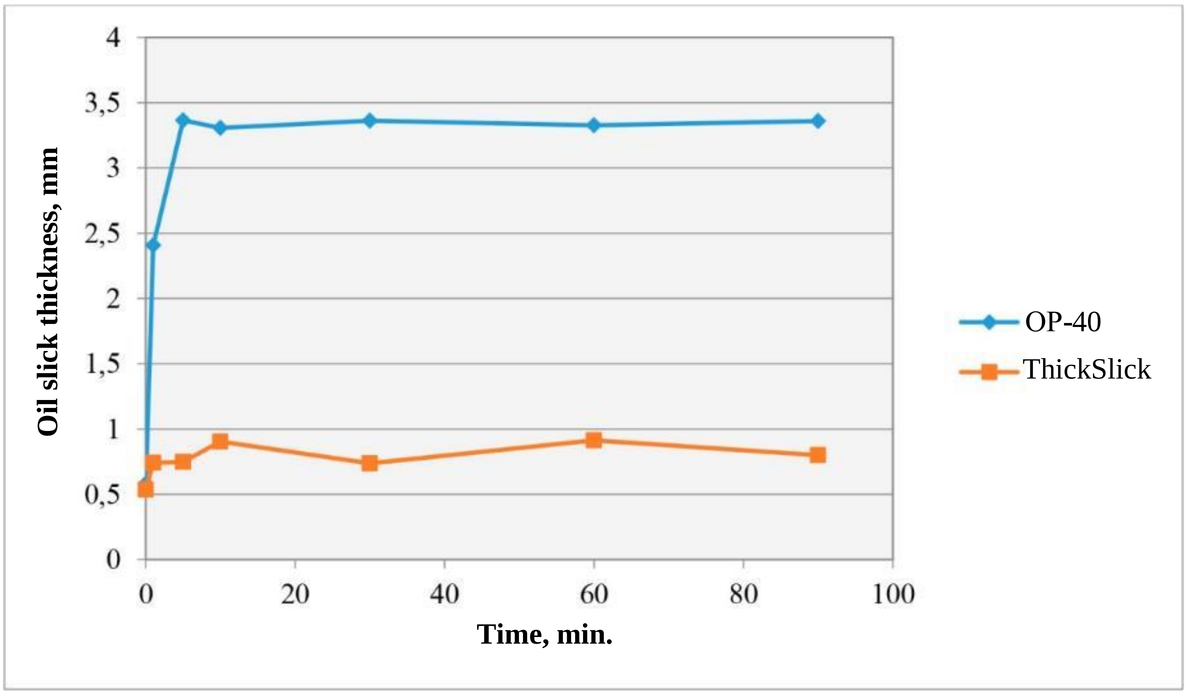


Figure 5. Herder effectiveness - Kashagan oil weathered at 200 °C on 6 ‰ 15 °C water

For comparison purposes, a series of tests were also undertaken with another oil produced in Kazakhstan, Buzachi crude oil. This oil has higher density than Kashagan crude, either fresh or weathered – see Table 1.

Oil		**Density (g/ml)**
Kashagan crude	Fresh	0.728
	Weathered at 60 °C	0.822
	Stripped at 200 °C	0.856
Buzachi crude	Fresh	0.918

Table 1. Densities of the oils

The key conclusions from the laboratory work were:

- ThickSlick and OP-40 herders are efficient agents to cause reduction in oil slick surface area and consequential thickening of spilled oil.
- The most effecitve herding for Kashagan crude was achieved with oil stripped at 200 °C.
- OP-40 was found to be the most efficient herder for Kashagan oil.
- Herder action does not depend on salinity of seawater used.
- Maximum herder action was manifested within a few minutes and maintained for one hour on average after its addition on the water surface.
- Both herders were more effective with Buzachi oil.

These outcomes aligned with the results from previous work on other oils reported through the JIP state-of-the-art study (SL Ross, 2015). It provided the basis for consideration of a field trial in Kazakhstan to confirm the viability of herding and burning of weathered Kashagan crude oil.

FIELD TRIAL

Preliminary work involved defining and developing the necessary procedure and actions according to Kazakhstan's environmental legislation for field tests, specifically:

- Review of legal requirements for the planned tests, which was defined as marine scientific research.
- Procedure for notifying the competent authority in the field of marine scientific research, which was the Ministry of Energy.
- Review of regulations for existing special environmental requirements.

Therefore, after notifying the Ministry of Energy about the upcoming field tests according to the environmental legislation, letters of invitation with details of the proposed field test activity were sent to relevant national and local authorities. This controlled field experiment was the first of its kind in Kazakhstan. The location for the test was boat basin of the North Caspian Ecological Response Base (NCERB) near Damba village of Atyrau Oblast – see Figure 6.

Figure 6. Location of the field test at NCERB

Preparations

In October 2018, batches of Kashagan Export crude oil were subjected to simulated weathering (evaporation) by air sparging (blowing air through the crude oil) at NCERB. This produced an evaporative loss of approximately 35% to 38%, equivalent to the oil that would remain on the sea's surface several hours after a spill.

The test was carried out on Wednesday 14 November 2018. Comprehensive safety assessments were undertaken at all stages of the project. The boat basin is 340 metres by 120 metres and connected by a channel to the River Ural and then on to the North Caspian Sea. This channel was protected by a standard boom during the test. Additionally, 300 metres of DESMI fire-proof Pyroboom® was anchored to create a 75 metre by 75 metre square area for the test, within the boat basin – see Figure 7.

A preliminary test was carried out in a 5 m^3 temporary storage tank the day before the test. This used ambient water from the boat basin and a small sample of the weathered oil. This oil was placed on the water within the tank and allowed to spread for a few minutes. Drops of OP-40 herder were then added around the oil and rapid herding was observed, with significant reduction in the oil's surface area. This provided confidence that the field trial would have a good chance of herding success under the ambient conditions.

Figure 7. Boomed area for the test

The overnight temperature had fallen to -11°C and some (around 1 cm thickness) ice was present within parts of the boomed area. An FRC (Fast Response Craft) was used to break up the ice prior to the test. The air and water temperature during the test were just above freezing and the wind was light. A quadcopter unmanned aerial vehicle (UAV) equipped with 4K video and thermal infra-red (IR) cameras was used to provide an overview of activities.

Test herd and burn

Four hundred litres of the artificially weathered crude oil were pumped from a vessel onto a wooden board suspended just above the water surface by a crane, so that the oil flowed out to produce a coherent oil slick – see Figures 8 and 9. The board and subsequent slick were inside the square of Pyroboom®. After the oil had been allowed to spread out to cover approximately 800 m^2 (i.e. roughly circular slick of around 30 m diameter with average thickness of <1 mm, being too thin to sustain combustion), an FRC within the boomed area was used to spray Siltech OP-40 herder around the periphery of the oil. This required guidance based on the thermal IR image from the UAV, clear communication from the test commander and skill on the part of the boat driver.

Figure 8. FRC used for herder and igniter application (left) and vessel used to pump oil in the test area (right)

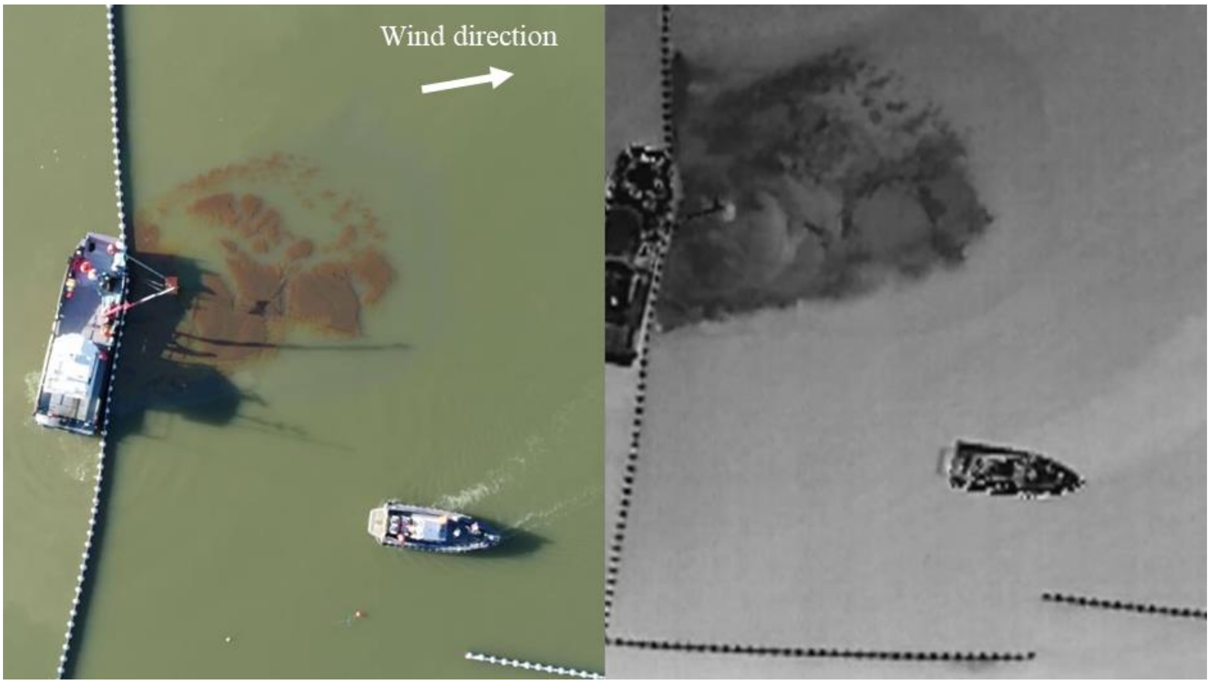


Figure 9. Visual (left) and IR (right) images from the UAV during oil release

After approximately one minute, the effect of the herder became apparent. The oiled area was observed to begin contracting, most obviously on the IR camera view but also by the FRC crew. After around 8 minutes, when the oil area had contracted to around 30 m^2, a member of the FRC crew placed an igniter into the thick oil. The igniter consisted of a marine flare strapped onto a plastic bottle containing gelled gasoline. Two empty plastic bottles provided floatation for the igniter. The oil on the water was ignited and then vapour from the oil supported its own combustion. A plume of black smoke was produced, and the oil burned vigorously with flames of 2 to 3 metres high and the oil burned for approximately 8 minutes – see Figure 10. The ignited slick gently drifted into a corner of the boomed area under the influence of the light wind, along with pieces of broken ice.

Figure 10. Oil ignition and burn

Another igniter was subsequently placed in a smaller area of herded oil that had become separated from the main oil slick and which had also drifted onto the edge of the ice in a corner of the test area. This oil was also burned. After the burning had finished a visual inspection showed a relatively small quantity of oil residue on top of the ice. This residue was manually collected. There was no evidence of the igniter, which was presumed to have been combusted with the oil.

ENVIRONMENTAL MONITORING

Monitoring was carried to assess the potential for impacts of the herder and/or burning of the oil. The locations of the stations where observations, measurements and sampling were carried out were determined in accordance with the “Rules for organizing and conducting industrial environmental monitoring during oil operations in the Kazakhstani sector of the Caspian Sea” (Order of the Minister of Energy dated November 20, 2014 No. 132 as amended on 09/26/2016 No. 429). Thus, 4 sampling stations (Nos. 2-5) were located along the perimeter of the harbour, one station (No. 6) was located in the centre between the stations and one station (No. 1) was located in the channel connecting the harbour with the river (Figure 11). Field observations and sampling were conducted on November 12 (baseline, before testing), November 14 (immediately after testing) and November 17 (3 days after testing) from a small-sized vessel.

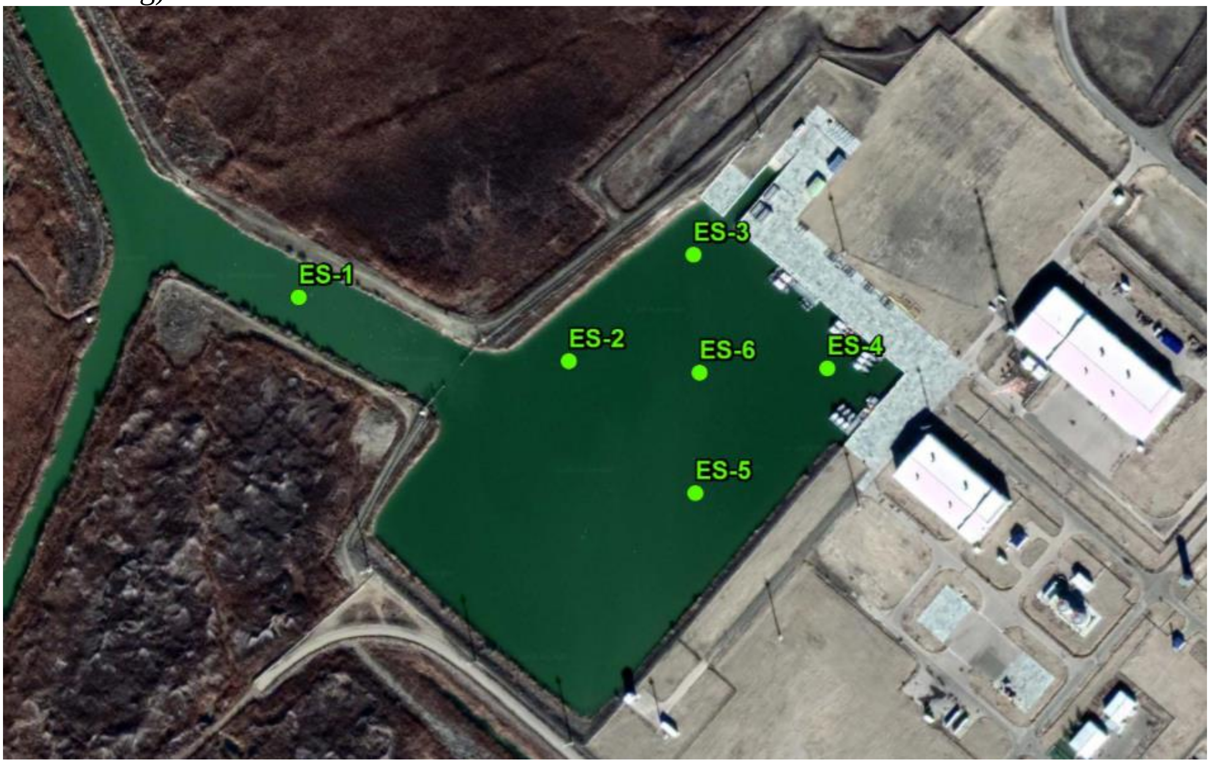


Figure 11. Locations of the environmental sampling stations

The parameters monitored were comprehensive, as required by the relevant regulation applied to the trial These are listed in Table 2, along with the summarized results.
The monitoring results detected no significant environmental impact from the application of herder or the burning of the oil.

Parameters	**Results summary**
Hydrophysical and hydrochemical indicators (pH, turbidity, temperature, conductivity, BOD5 and organic carbon)	There were variations in the measurements, but these showed no consistent trend across the sampling points. At most stations, measurements returned to background values or decreased compared to them throughout the period.
Total hydrocarbons, phenols and PAH	No change in total hydrocarbons during or after the trial. All phenols and all PAHs (except pyrene) were below detection limits. The trial had no effect on pyrene concentration.
Heavy metals	No impacts on measured levels.
Synthetic surfactants	
Air parameters (NO, NO_2, SO_2, CO, H_2S)	There was no exceedance of permitted levels for all measured parameters.
Microbiology	Qualitative and quantitative composition of the microflora of sediments did not change.
Phyto- and Zoo-plankton	No significant variation in the diversity and abundance of phytoplankton. Zooplankton composition remain unchanged.
Macrozoobenthos	No effect on the composition and structure of the macrozoobenthos.
Avifauna (birds)	No impact on species recorded before during and after the trial.

Table 2. Monitored parameters

CONCLUSIONS

This is the first time that this type of field trial has been conducted in Kazakhstan , resulting in the successful herding and burning of 400 L weathered crude oil in open water with ice present. The test confirmed the feasibility of using herders and in-situ oil burning as an oil spill response technique in the Kazakhstan Sector of the Caspian Sea.

Analysis of the images captured by the UAV, based on reduction of oil’s surface area in both the visual and IR spectra indicated removal by burning of at least 90 - 95% of the spilled oil.

The post-test water analysis shows that pollutant concentrations returned to baseline after the herder application. The analysis did not reveal any effect of the herder on the bottom sediments. No impact of tests on biodiversity was identified; the species composition, species quantity and diversity fluctuated only slightly during the test period (organisms, species, etc.).

Consideration is underway as to how herder can be added to the list of approved chemicals for oil spill response in Kazakhstan. Dispersants and in-situ burning are currently regulated under the Environmental Code (Ministry of Justice, 2007) and a Ministry of Energy Order (#247) on oil spill response methods. It is anticipated that these regulations can be developed to include herders. It will then be possible to incorporate the herd and burn technique into contingency plans, based on NEBA/SIMA justification. This will have the potential to improve response option choice and increase the speed and effectiveness of response to incidents in either broken ice or open waters.

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