Experimental Study of High Pressure Washing Efficiency of Oily Rocky Shores: Influence of Viscosity of Oil and Cleaning Agent Use

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ABSTRACT

Following an oil spill on rocky shores, the efficiency of high pressure washing techniques is influenced by many parameters such as the nature of the oil, the substrate nature and the settings of the high pressure washer, (temperature and pressure). An experimental program was initiated at Cedre in order to assess the influence of (i) the viscosity of the oil and (ii) the soaking time of the cleaning agent in term of efficiency of high pressure washing techniques.

The experimental study was conducted with the “washing robot”, an automated tool developed at Cedre in order to recreate the high pressure washing technique as it is used on the shores after an oil spill. The polluted rocky shores were simulated by using granite tiles artificially coated with a mixture of crude oil and heavy fuel oil at various viscosities. For each viscosity tested, (from 60 to 23 000mPa.s), a batch of 30 tiles was polluted and cleaning operations were performed at various temperatures, (from 15 to 77°C) and pressures (from 5 to 100 bar). After cleaning, the amount of oil remaining on the tiles was determined by spectrophotometry.

The experimental results highlighted the importance of temperature on the efficiency of the washing technique: over a temperature of 50°C, the viscosity had no influence on the amount of oil remaining on tiles and a pressure of 30 bars was sufficient for a cleaning rate of 80%. When a cleaning agent was previously applied on the tiles, it was possible to obtain a total removal of the oil even if low temperature and pressure settings were used. Moreover, a soaking time over 3 minutes did not ensure better cleaning rate in the tests conditions.

INTRODUCTION

As most of cleanup techniques employed on the shoreline following an oil spill, the efficiency of high pressure washing (HPW) technique is subjected to the environmental conditions (temperature, substrate nature, …) and to the chemical properties of the spilled oil (nature, viscosity, weathering degree). Moreover, most of the high pressure washers allow the setting of temperature and pressure of the water jet which influence the efficiency of the technique. In order to define the most appropriate washing conditions (combination of temperature and pressure) and to test the efficiency of shoreline cleaning agents, *Cedre* has developed the “washing robot”, an automated tool which recreates a high pressure cleaning as it is undertaken on the coastline after an oil spill. The equipment consists in a robot which moves a HPW nozzle on a polluted substrate. The robot is controlled by an automated system which ensures a repetitive and reproductive movement of the nozzle. The polluted substrate is simulated by using granite tiles artificially polluted in the laboratory. Each tile is exposed to the water jet and the amount of oil remaining at the end of the test is determined by spectrophotometry.

The study was conducted into two stages. The objective of the first stage was to assess the influence of the oil viscosity. During the second stage, we focused on the cleaning agent use and especially the influence of soaking time.

MATERIALS AND METHODS

The Washing Robot

The equipment (Figure 1) is composed of the following main items:

- a stainless steel frame with an internal volume of about 300 litres,
- a trolley with the washing nozzle,
- a support frame for the polluted hard surfaces,
- two electric screw jacks allowing horizontal and vertical movements of the trolley,
- a high pressure water washer (as can be found in French POLMAR stockpiles),
- a programmable control driving the two electric screw jacks,
- a seawater supply with temperature regulation

The equipment ensures the consistent washing conditions for all the successive tests (spraying width, speed and distance). This ensured that the hard surfaces (granite tiles) were washed exactly in the same way, and comparative tests could be performed.

The settings used in the present study are presented in Table 1.

Hard Substrates

The rocky shoreline was simulated by using granite tiles (*Quartzite Astera Gris*) characterised by dimensions of 15 x 15 x 2 cm. The surfaces of the tiles were not smoothed down in order to recreate a substrate as natural as possible. Oil was applied on the tiles in the laboratory using a paintbrush; after oiling, tiles were held in a horizontal position for 24 hours (impregnation time) and then, in a vertical position during 96 hours to let the excess oil drain (Jézéquel *et al*., 2003). A light oil weathering of 24 hours was recreated by placing all the tiles in a seawater bath with slight agitation.

Quantification of oil remaining on tiles after cleaning

After cleaning by using the washing robot, tiles with the remaining oil were stored at 5°C prior to analysis. The oil was extracted by immersion in methylene chloride (pestipur quality) in an ultrasonic bath for 15 minutes and, after drying on sodium sulphate (activated at 400°C overnight), diluted to appropriate concentrations. The absorbance was measured at 580 nm by using a spectrophotometer (UNICAM, UV/Vis spectrophotometer). Cleaning rates correspond to the amount of oil extracted from the tiles after cleaning versus the initial amount of oil (before cleaning).

Physical properties of the oil

Different mixtures of an Arabian Light crude oil topped at 110°C (BAL 110) with a heavy fuel oil – RM500 (classification ISO8217, 2005) were prepared in order to obtain a viscosity range from 60 to 23000 mPa.s (measured using a Haake VT 550 viscosimeter at 12°C, 10 s^{-1}). Figure 2 presents the evolution of viscosity according to the amount of RM500 added to the Arabian Light. [Number in brackets corresponds to the amount of oil extracted from the tiles (*n*=3) at the end of the pollution phase.] The relatively high standard deviation value was mainly due to the surface roughness. The oil layer applied on the tiles was estimated between 6 and 8 µm, which is in agreement with a layer of oil which could remain on rocks after the manual scraping operations systematically performed after an oil spill.

The value of the standard deviation obtained with crude oil appeared high compared to those obtained with the others product: 0.18 against 0.07, 0.07, 0.02 and 0.03. This was explained by the persistence of a significant proportion of crude oil in the fissures of the tiles at the end of the solvent-extraction process. This observation was not confirmed with the more viscous product and, consequently, the standard deviation appeared lower.

Cleaning Agent

The Ketrul D85 cleaning agent, a solvent based product, was applied at the oil surface using a vaporizer. Polluted tiles were weighted and the cleaning agent was applied until the ratio of 1:2 between cleaning agent and oil was obtained. To study the influence of soaking time, different times of exposure to the cleaning agent were used: 1, 3, 10, 20 and 30 minutes.

RESULTS

Figures 3 and 4 present pictures of tiles after washing, respectively for 60°C / 100 bars and 77°C / 100 bars combination. The visual comparison of these pictures highlights an increase of the water jet width when using warmer water. Consequently, in order to allow comparison of results between all the parameters studied (changes of pressure and temperature), a picture of each tile was taken after washing and the surface exposed to the water jet measured using a dedicated software (ImageJ, v.1.37). Results were then corrected according to the surface really exposed to the water jet.

Influence of viscosity on cleaning rate

Figure 5 presents the percentage of oil remaining on tiles after washing for each viscosity tested according the HPW settings (temperature and pressure). As it was previously observed with tiles polluted with crude oil, a significant proportion of crude oil remained trapped in the fissures of the rocks after washing and solvent-extraction, which leads to the overestimation of the cleaning rate. Consequently, no data are presented for the tests performed with crude oil.

Considering the two lowest temperatures, the maximum amount of oil washed out from the tiles were in the range 40/60% when using a temperature of 20°C and 60/80% at 30°C with the highest pressure available (100 bars). Except for the more viscous oil, there were no differences of cleaning rates for oil with a viscosity below 16 000 mPa.s. At a temperature of

45°C, results did not differ significantly between the different viscosities and a maximum of 70/80% of oil was washed out from the tiles with a pressure of 100 bars. For the highest temperatures (60 and 77°C), a maximal cleaning of the tiles was obtained for the less viscous oil with a pressure of 20 bars. For the other product with a viscosity between 9 000 and 23 000 mPa.s, there was no difference of results and a maximum of 80-90% was obtained for a pressure of 40 bars.

Influence of soaking time on cleaning rate

The influence of soaking time was studied with tiles polluted with the 9 000 mPa.s viscosity product (12°C, 10 s^{-1}). For each soaking time, a batch of 30 tiles were polluted, treated with the cleaning agent during 1, 3, 10, 20 and 30 minutes, and then exposed to a water jet with a temperature from 20 to 77°C and a pressure from 5 to 100 bars. The results are presented for each temperature in figure 6.

Surprisingly, the results did not differ significantly between the different conditions tested. Whatever the temperature and the soaking time used, the best effectiveness of washing was obtained for a pressure of 20 bars. For the lowest temperature (20°C), the cleaning rates tended to be higher with increasing soaking times. For a temperature in the range of 30 - 45°C, a soaking time of 1 minute seemed to be insufficient to obtain a complete cleaning of the tiles. With a water jet of 60°Cand 77°C, the results obtained were not dependent of the soaking time.

CONCLUSIONS

The objective of the experimental study was, first, to assess the difference of performance of a high pressure water jet cleaning on a rocky shores polluted with oils at different viscosities. Secondly, to study the influence of the soaking time of a cleaning agent sprayed over the polluted substrates. In order to conduct this experiment, a polluted rocky shoreline was simulated by coating granite tiles with oil. The hydraulic washing was simulated using the “washing robot”, an automated tool developed at *Cedre*.

The results of the tests highlighted the influence of viscosity on the high pressure washing effectiveness for temperatures below 45°C. This was not observed for higher temperatures for which there was no need to apply a pressure greater than 30 bars as the optimum cleaning rate was obtained with this setting whatever the viscosity tested. In respect of soaking times performed with a 9000 mPa.s viscosity product, the tests pointed out that with a temperature of 20°C (or less), the efficiency of the cleaning agent was dependent on the soaking time. If the high pressure washer output was heated , this soaking time decreased to 3 minutes for temperature between 20 and 60°C and to 1 minute if a temperature higher than 60°C was used. Considering the environmental impact of this technique, as heat and high pressure can be detrimental to certain environments, the temperature and pressure should be adjusted depending on the nature and sensitivity of the substrate, and also to obey the specific restrictions and recommendations which may exist for certain ecologically sensitive sites.

The results presented in this paper were obtained during the first series of experiments performed with this equipment. In the future, rather than studying the influence of different parameters on the effectiveness of the technique, it will be useful to perform all the tests on specific products, (cleaning agent or pollutant) in order to obtain data helpful for the definition of operational recommendations in case of accidental spill.

BIBLIOGRAPHY

Jézéquel, R., L.Menot, F.X. Merlin, and R.C. Prince, "Natural Cleanup of Heavy Fuel Oil on Rocks: An In Situ Experiment", *Marine Pollution Bulletin*, 46 (8), pp. 983-990, 2003.

International Organization for Standardization. ISO 8217, *Petroleum Products* -- *Fuels (class F)* -- *Specifications of Marine Fuels, Edition: 3, Stage: 90.92*, 13p., 2005.

Figure 1. The Washing Robot.

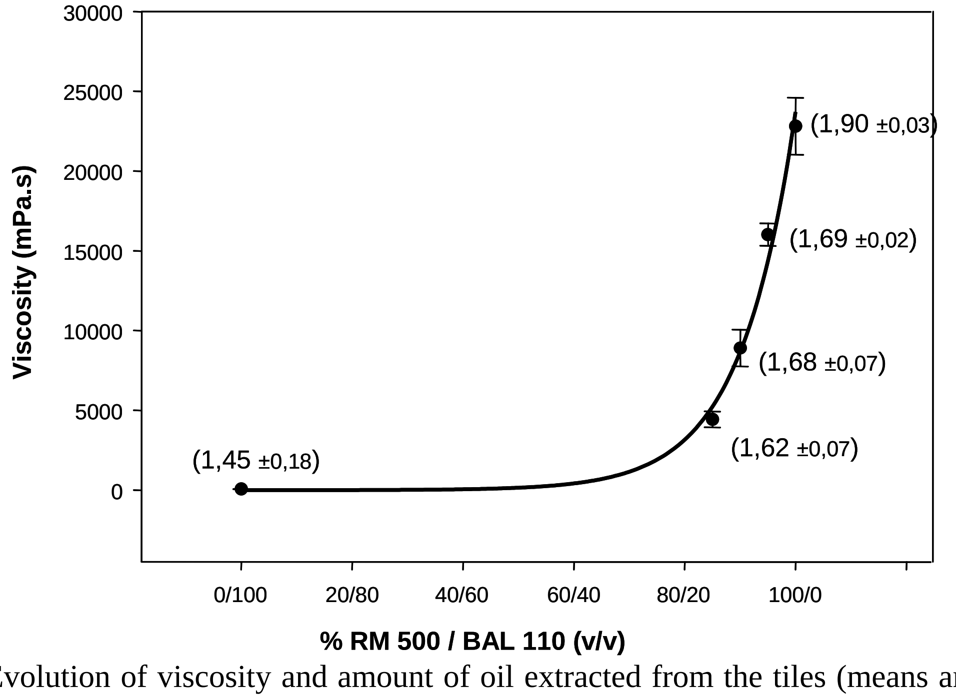

Figure 2. Evolution of viscosity and amount of oil extracted from the tiles (means and standard deviation, *n*=3) for the different mixture of RM500/ BAL 110.

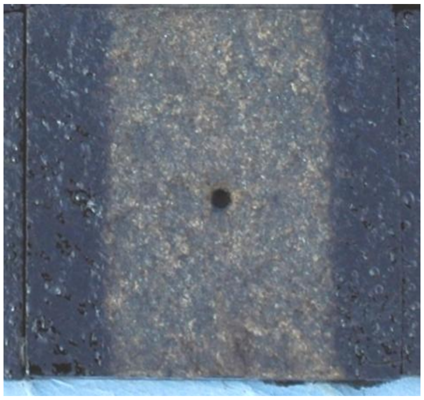

Figure 3. Polluted tiles after washing at 60°C/100 bars.

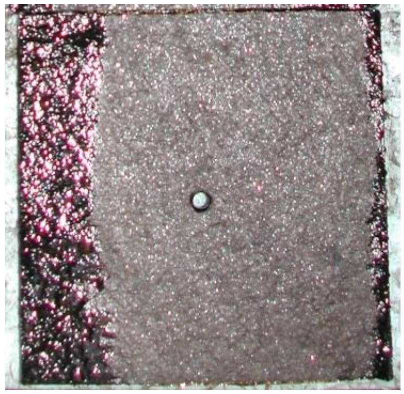

Figure 4. Polluted tiles after washing at 77°C/100 bars.

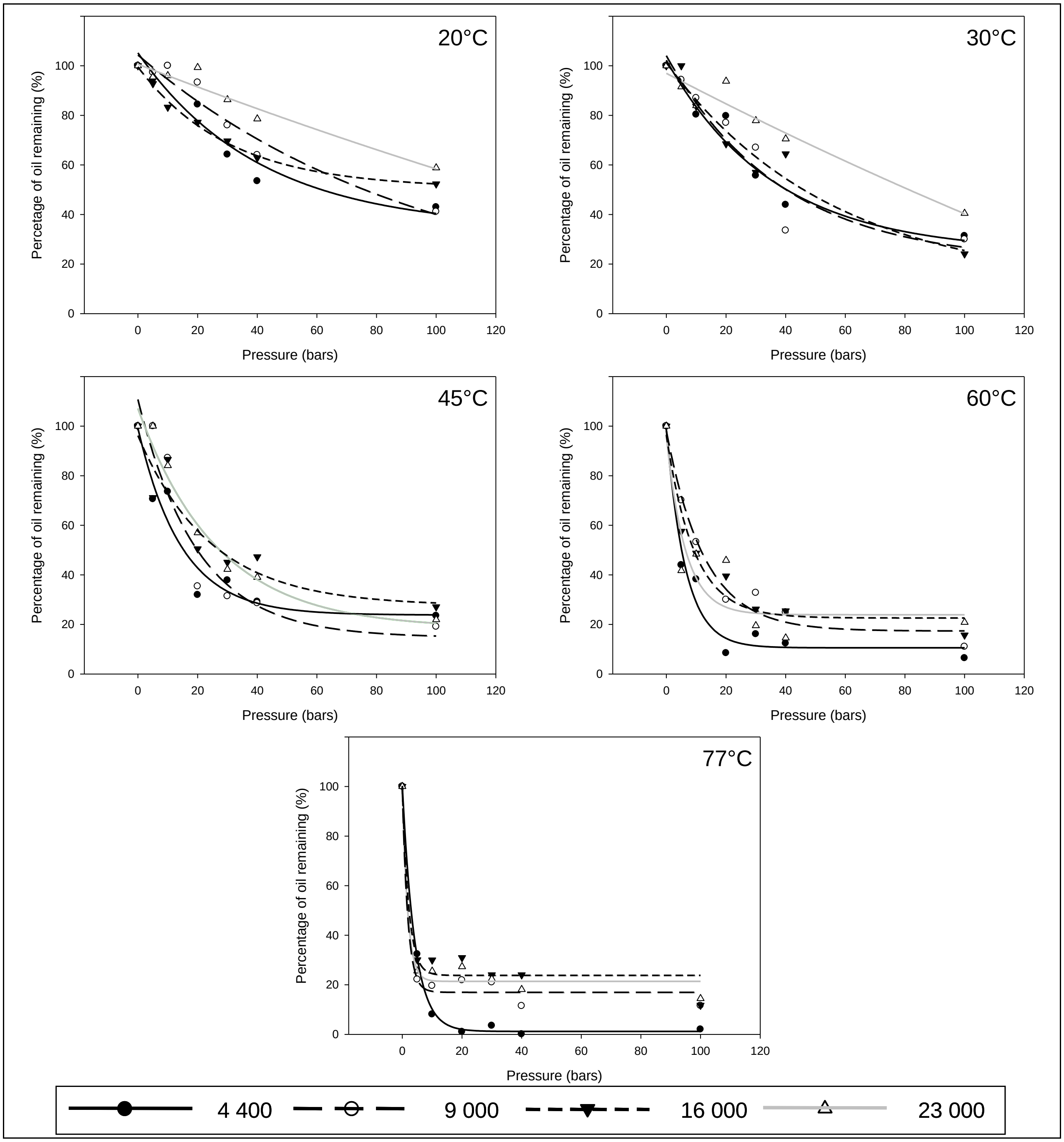

Figure 5. Percentage of oil remaining on tiles according to temperature (°C) and pressure (bars) of the water jet for the different viscosities (mPa.s).

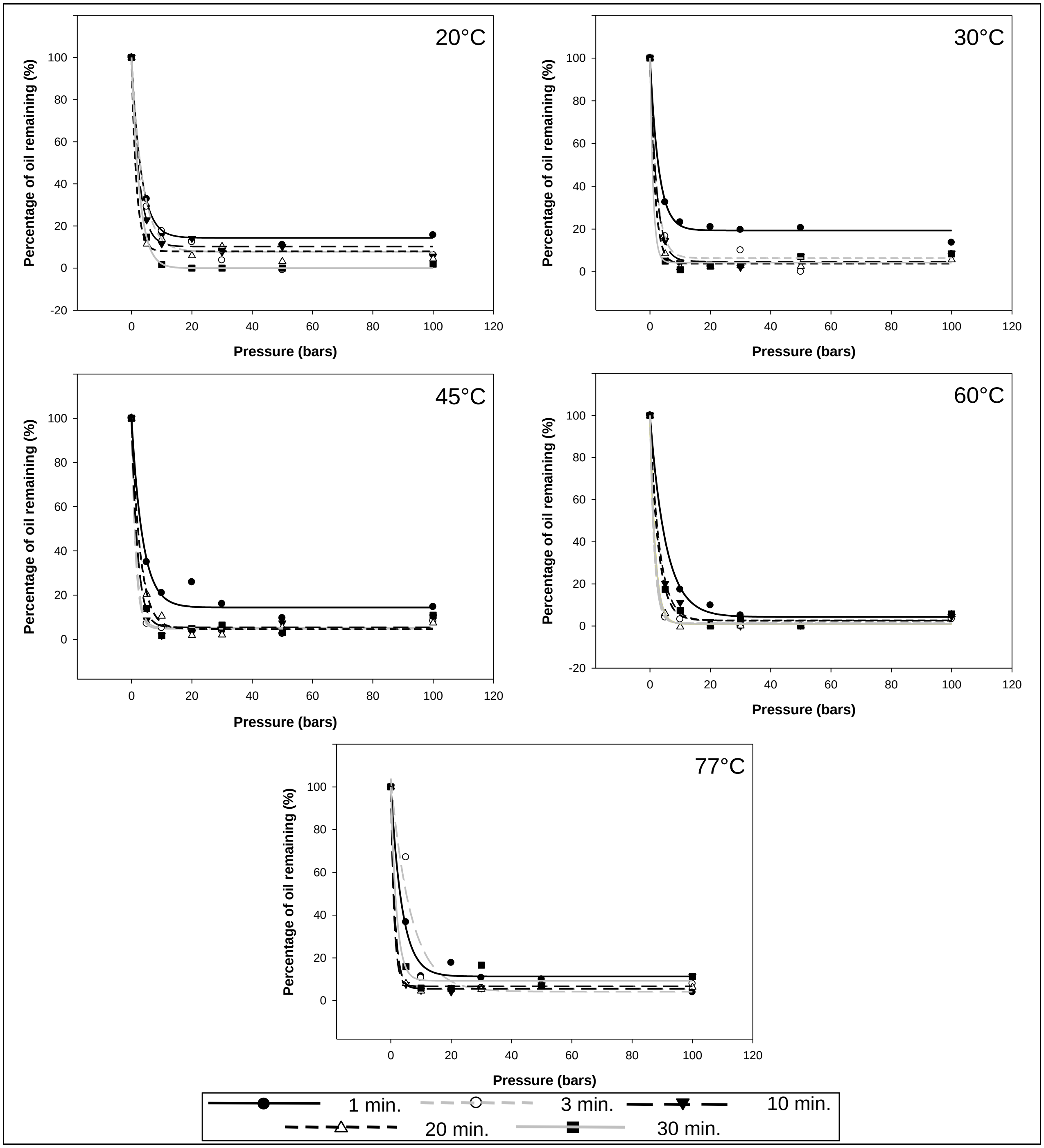

Figure 6. Percentage of oil remaining on tiles according to temperature (°C) and pressure (bars) of the water jet after different soaking time of cleaning agent (minutes).

Table 1. Settings of the washing robot.

High Pressure Washer	Karcher HDS 895S
Pressure range	5, 10, 20, 30, 40, 50, 60 and 100 bars (*)
Temperature range	15, 30, 45, 60 and 77°C (*)
Nozzle	Power buse Karcher. diameter 0.55 mm, 25° angle
Sweep frequency	3.8 $cm.s^{-1}$
Distance between hard substrate and nozzle	15 cm

(*): 100 bars and 77°C were the maximum specifications available with the hydraulic washer used during the present study.