IMPACT: International Journal of Research in Applied,
Natural and Social Sciences (IMPACT: IJRANSS)
ISSN (P): 2347-4580; ISSN (E): 2321-8851
Vol. 5, Issue 9, Sep 2017, 147-154

THERMAL INFRARED SCANNING FOR EVALUATING OIL PLUME THICKNESS CONTAMINATING GROUNDWATER

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ABSTRACT

The characteristic that all objects emit a certain amount of black body radiation as a function of their temperatures was used in tracing the distribution of temperature in that black body. Generally speaking, the higher an object's temperature, the more infrared radiation is emitted as black-body radiation. A special camera can detect this radiation in a way similar to the way an ordinary camera detects visible light. It works even in total darkness because the ambient light level does not matter. This makes it useful for rescue operations in wells.

The area where the idea is applied located at the Al Giran site west of Tripoli the capital of Libya. Al Green subjected to an oil leakage took place along the W10 Al Zawya-Tripoli pipeline. Taking the advantage of the difference between the temperature of the water and oil with their ambient, thermal scanning executing on the polluted site in order to measure the thickness and areal extent of the oil plume polluting the groundwater.

The temperature of the fluids (Oil and Water) measured along the selected depth of the 25 drilled wells. The measured temperatures showed variation along the depth from ambient temperature, as well as aurally. This variation in oil and water temperatures enabled detecting the water, oil contact and its areal distribution on the polluted site subjected to remediation.

Comparing the time and cost of the technique applied to sampling groundwater technique appeared to be faster and cheaper, besides giving more informative data.

KEYWORDS: Thermal Infrared, Contamination, Groundwater Monitoring, oil Pollution

INTRODUCTION

Oil is one of the most common types of water pollution. Oil pollution will still occur as accidents and the law and regulations break from time to time. Ming and Tuv (2001) mentioned that oil in water has different forms dissolved, dispersed and floating (free oil). All forms need monitoring system that is properly calibrated and maintained together with a good sampling system. Although, they cannot replace the laboratory analytical methods, they are increasingly considered as a mean in a regulatory compliance monitoring.

Ming and Tuv (2001) also mentioned that on line oil- in- water monitors are mainly designed for detecting oil present in water dissolved and are dispersed, and are not suitable for detecting oils floating on the surface water. Therefore, oil-on-water detection instruments are needed and in many cases offer simpler and cost effective ways of providing warning and environmental monitoring system.

The current monitoring systems used are infrared, light scattering/turbidity, UV absorbance, UV fluorescence, Photoacoustic sensor, image analysis, fiber optic chemical sensor, Ultrasonic. In this work the infrared thermal method was used as a monitoring system in tracing oil contaminating underground water.

IR THEORY

Infrared energy is just one part of the electromagnetic spectrum, which encompasses radiation from gamma rays, x-rays, ultraviolet, a thin region of visible light, infrared, terahertz waves, microwaves, and radio waves. These are all related and differentiated in the length of their wave (wavelength). All objects emit a certain amount of black body radiation, as a function of their temperatures.

Generally speaking, the higher an object's temperature, the more infrared radiation is emitted as black-body radiation. A special camera can detect this radiation, in a way similar to the way an ordinary camera detects visible light. It works even in total darkness, because the ambient light level does not matter. This makes it useful for rescue operations in smoke-filled buildings and underground.

APPLICATION

Towards the end of the 1990s, the use of infrared was moving towards civil use. There was a dramatic lowering of costs for unsold arrays, which, along with the large increase in developments lead to a dual way use market, between civil and military (Rogalski, 2003). These uses include environmental control, building/art analysis, medical, functional diagnostics, and car guidance and collision avoidance systems (Corsi, 2010; Corsi, 1991; Kozlowski and Kosonocky, 1995; Corsi, 1996; Razeghi, 1998; Rogalski, 2000; Corsi, 2012).

For use in temperature measurement, the brightest (warmest) parts of the image are customarily colored white, intermediate temperatures reds and yellows, and the dimmest (coolest) parts black. A scale should be shown next to a false color image, to relate colors to temperatures.

IR CAMERA

A **thermographic camera** (also called an **infrared camera** or **thermal imaging camera**) is a device that forms an image using infrared radiation, similar to a common camera that forms an image using visible light. Instead of the 400–700 nanometer range of the visible light camera, infrared cameras operate at wavelengths as long as 14,000 nm (14 µm). Their use is called thermography.

The core of our payload is an IR camera; in detail, we use the model P65 manufactured by FLIR systems (Figure, 1). Main technical specification of this mode is:

- 640 x 480 infrared Detector.
- Thermal sensitivity: (45 mm).
- High accuracy +/- 1%.
- Dynamic Details Enhancement (DDE).
- Built-in GPS.

- WLAN remote control and display.
- 3.2 Megapixel visible light cameras (this feature permits a data-fusion between IR and visible).

Figure 1: IR Camera Model P65

THE PROBLEM AND OBJECTIVE

The area which faces a problem of oil contamination is located at Al Giran, bounded by latitude N 32 50’42” and crossed by longitude E 13 03’18” west of Tripoli the capital of Libya (Figure, 2). Al Green subjected to an oil leakage took place along the W10 Al Zawya-Tripoli pipeline. The main object required for the remediation of the AL Giran Site is to achieve a reduction in underground water contamination, and the hazards it imposes according to the EU Standard, protecting the environment and the surrounding area.

Figure 2. Location of the Contaminated Area.

PUMP-AND-TREAT REMEDIATION

Pump-and-treat remediation of ground-water contamination are planned, or have been initiated at many sites across the world. Regulatory responsibilities require that, adequate oversight of these remediation be made possible, by structuring appropriate monitoring criteria for monitoring and extraction wells. These efforts are nominally directed at answering the question: What can be done, to show whether a remediation is generating the desired control of the contamination? Recently, other questions have come to the forefront, brought on by the realization that many pump-and-treat remediation may not function as well as has been expected: What can be done to determine whether the remediation will meet its timelines? and what can be done to determine whether the remediation will stay within budget? Conventional wisdom has it, that these questions can be answered by the use of sophisticated data analysis tools, such as statistical & graphical analysis of ground-water flow and contaminant transport. The analysis can indeed be used, to make predictions about future performance, but such predictions are highly dependent on the quality and completeness of the field and laboratory data utilized.

REMEDIATION PERFORMANCE EVALUATIONS

Ground-water data are collected during remediation, to evaluate progress toward goals specified in the work plan. The key controls on the quality of these data are the monitoring criteria, that are selected and the locations at which those criteria are to be applied. Ideally, the criteria and the locations would be selected on the basis of a detailed site characterization, from which transport pathways prior to remediation could be identified, and from which the probable pathways during remediation could be predicted. The monitoring criteria and locations should also be chosen in such a way, as to provide information on what is happening both down gradient of the plume boundary and inside the plume. Monitoring within the plume makes it possible to determine, which parts of the plan are being effectively rernediated and how quickly. This facilitates management of the rendition, well field for greatest efficiency; for example, by reducing the flow rates of extraction wells, that pump from relatively clean zones and increasing the flow rates of extraction wells, that pump from zones that are highly contaminated. By contrast, the exclusive use of monitoring points down gradient of the plume boundary does not allow one to gain any understanding, about the behavior of the plume during remediation, except to indicate out-of-control conditions, when contaminants are detected.

THERMAL PATTERN OF THE OIL THICKNESS

Different shots of IR Thermography applied for different depths at 20m, 23m, 26m, & 29m. The shots taken for the selected depth, record the distribution of temperature in each mentioned depth.

Figure (3), represents the shots at 23m & 26m depth in the well BH 16B. The temperature detected on the surface of the fluid in these two depths indicate that, there is no oil plume in this well as there is a difference between the temperature of the ambient, and the water in the well (water less temperature than ambient = 25°C).

The IR shots represented by the figure (4), for the depths (23m, 26m, & 29m) for the well BH16A showed the oil spot brighter than the water (darker in colour). The temperature registered in the middle of the spot showed an increase from that of the ambient. The increment of the temperature with depth referred to the existence of the contaminated oil plume.

If we suppose that, water exist in the well not contaminated by hydrocarbons, then the temperature should decrease with depth. The case in this well, reflects the opposite situation, which let us to conclude that, the temperature behavior reflecting the existence of contaminated material (hydrocarbon).

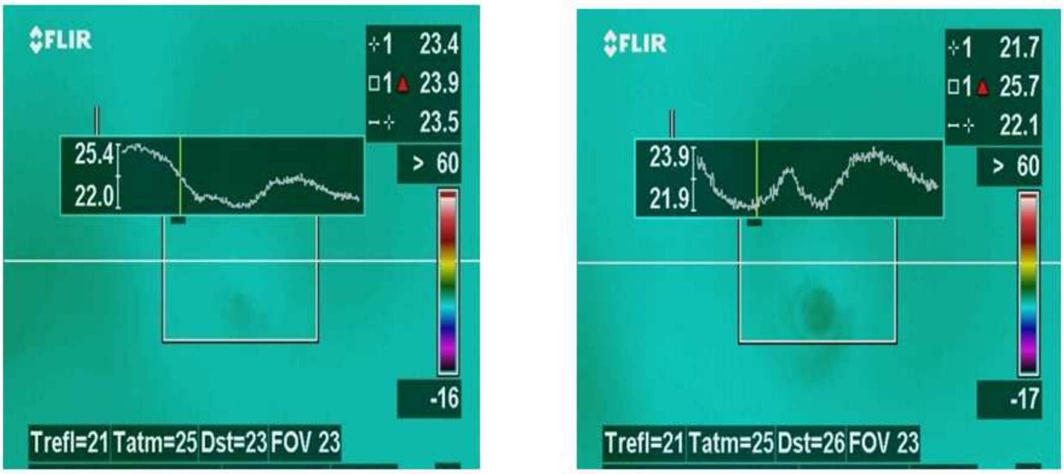

Figure 3: Example of Thermal Pattern of Liquid Flux of Groundwater at Different Elevations of Well BH (16B) (No Oil Plume)

Another example of IR shots of the well WW14 (Figure, 4), showed the same temperature behavior with depth as that for the well BH16A. This attempt was carried out, to justify the application of the IR to detect the contaminated thickness in the well.

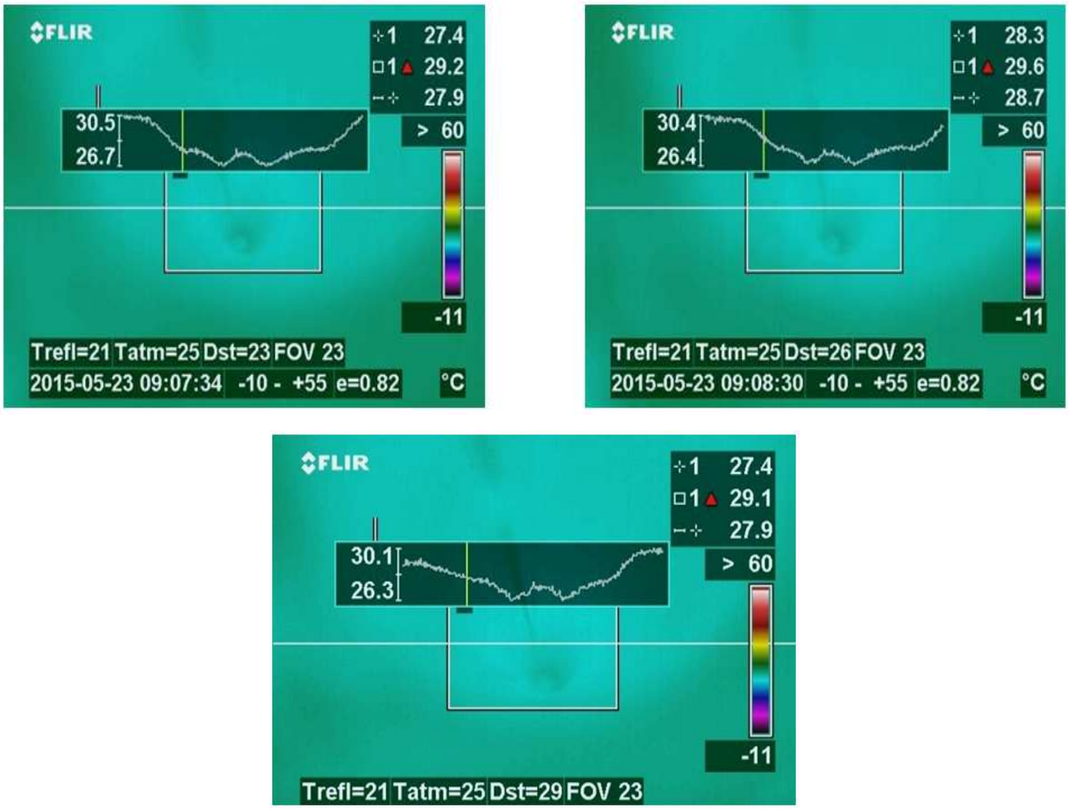

Figure 4: Example of Thermal Pattern of Liquid Flux to Ground Water ”Dark Spot” and Plume of Liquid Surrounded at Different

Elevations of Wells BH (16A and WW14).

Ten wells in the contaminated site were selected, covering wells with oil palm and those without for the aim of implementing IR in tracing hydrocarbon distribution. Contour mapping (Figure, 5) was constructed for different depths (23m, 26m, & 29m), showing temperature distribution. The maps showed that, the contamination at the present stage condensed and restricted to the south and southwest side of the studied area.

The contour maps constructed for the oil-groundwater temperature were compared with the contour map, constructed for the oil plume thickness (Figure, 6), in order to evaluate the IR attempt to measure contamination thickness. The comparison indicates that, both attempts coincide with each other, in that contamination condensed in the south and southwest side of the studied area.

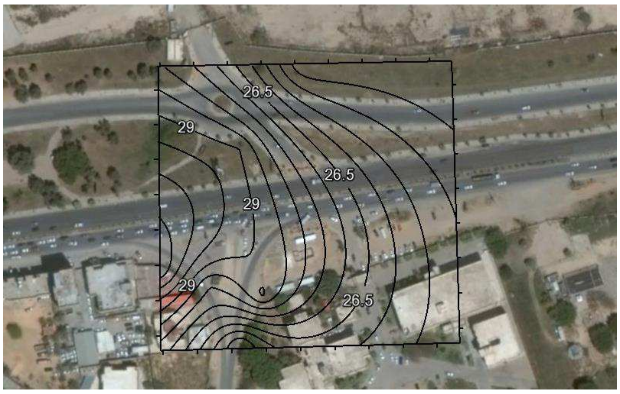

Figure 5: Temperatures Distribution at 23 M Depth

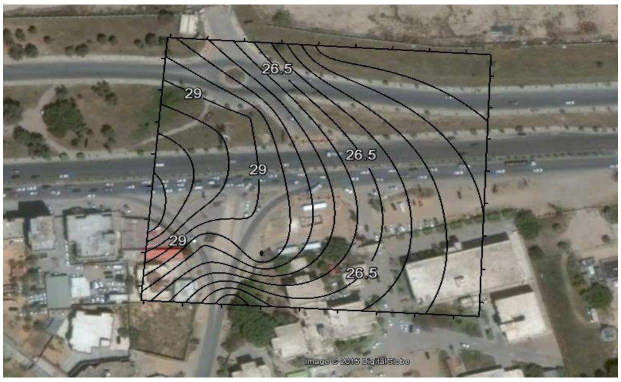

Figure 6: Temperatures Distibution At 26 M Depth

Temperatures Distibution At 29 M Depth

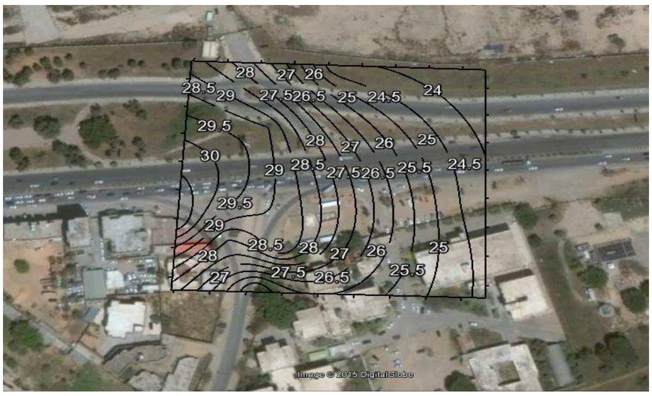

Figure 7: Contour Mapping of the Groundwater-Oil Temperature In the Contaminated Site For the Ten Selected Wells At Different Depths.

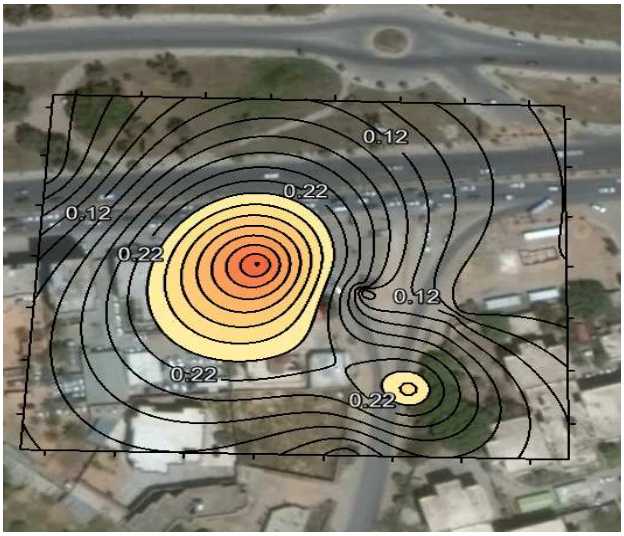

Figure 8: Oil Plume Thickness in the Contaminated Are Recorded In May 2015.

CONCLUSIONS

The cases studied for the purposes of this contribution, validated infrared thermography as an optimal tool to support ground water contamination monitoring.

By using infrared thermography, specialized and advanced techniques of data analysis and visualization can trace several contamination problems: locating pollution point sources and finding the right path between sources and targets.

As outlined in mapping temperature, the oil plume contaminated groundwater can easily outline and lets evaluating pump-and-treat in the field of contamination remedy. It proofs the easy way in the application giving informative information with less cost.

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