

A Geotechnical and Geochemical Characterisation of Oil Fire Contaminated Soils in Kuwait

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Abstract: As a consequence of the Saddam Hussein 1991 Iraqi led invasion of Kuwait more than 700 oil wells were set fire to as part of a scorched earth policy while retreating from the country. This action created a series of “oil lakes” and hydrocarbon contamination within the desert causing serious environmental damage. Some 23 years later after the fires were extinguished the ground affects of these actions can still be detected. This paper will present the results of a detailed geotechnical and geochemical investigation into the current ground conditions now present in the Burgan Oil Field some 35km south of Kuwait City. Detailed geotechnical testing together with hydrocarbon analysis using a Gas Chromatograph - Mass Spectrometer (GCMS) have been carried out on samples from varying depths within the Greater Burgan Oil Field. A detailed geological, geotechnical and geochemical ground model has been developed to present the findings of these investigations. The area under study has major development plans for both housing and infrastructure. Subsequent Quantitative Human Health Risk Assessments have been undertaken to determine the potential levels of risk posed to any future urban developments within these affected areas. The paper will report on this assessment detailing the hazards posed and the tools used to assess them. Potential risks will be discussed and mitigation and management scenarios will be highlighted.

Problem Addressed

- The State of Kuwait has experienced serious environmental damage as a consequence of the formation of multiple oil lakes & hydrocarbon contamination resulting from the destruction caused in the Gulf War of 1991
- Of the 810 active oils wells operating in Kuwait in 1991, 730 were damaged or set ablaze during the conflict
- This research set out to assess the hydrocarbon contamination & geotechnical effects of the oil fires still being encountered some 20 years plus after the war

Site Description

- Area under study was located in the Greater Burgan oilfield (Fig. 1)
- The Greater Burgan field is the largest clastic oil field in the world covering an area of 838km²
- Oil field is subdivided into the Burgan, Magwa and Ahmadi sectors based on the underlying geological structure
- At the height of the destruction smoke plumes from the Greater Burgan oil fires extended over 50km from the well sites up to an altitude of 2.5km
- Spillages from ruptured pipelines resulted in numerous oil lakes which caused extensive contamination & environmental damage.

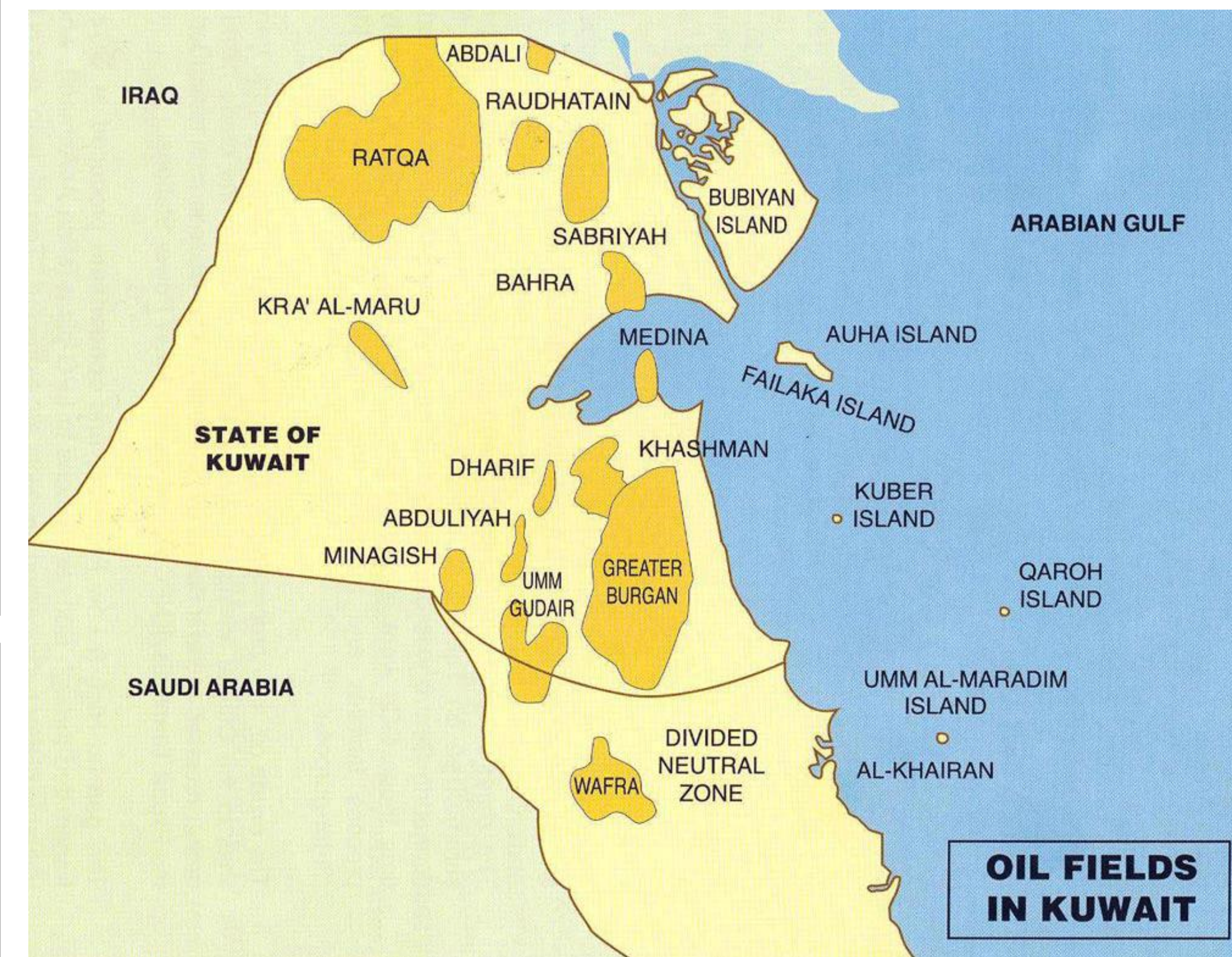


Fig 1. Oil fields in Kuwait (Kuwait Oil Company KOC).



Fig 2. Burning oilfields during Operation Desert Storm, Kuwait. Environmental damage caused by the fires & oil lakes have had a lasting impact on Kuwait's ecosystem (USACE, KOC).



Fig 3. Aerial view of the oil lakes that formed as a result of the damage inflicted by retreating forces. (KOC).

GENERALISED STRATIGRAPHY		HYDRO GEOLOGICAL UNITS
QUATERNARY SEDIMENTS (< 30m)	Unconsolidated sands and gravels, gypsiferous and calcareous silts and clays	Localised Aquifers
KUWAIT GROUP	DIBDIBBA FORMATION (200 - 200m)	Aquifer
	FARS & GHAR FORMATIONS	Aquifer
	Unconformity	Aquitard
HASA GROUP	DAMMAM FORMATION (60 - 200m)	Aquifer
		Aquitard locally
	RUS FORMATION (20 - 200m)	Aquiclude
	UMM ER RADHUMA FORMATION (300 - 600m)	Aquifer
	Disconformity	Aquitard
ARUMA GROUP	Limestone and shaly limestone	Aquifer

Site Geology – Solid & Superficial

- Kuwait is dominated by rocks of Tertiary age (Palaeocene to Eocene)
- Limestones, dolomites and evaporitic sequences (anhydrites) from the Umm Er Radhuma, Rus & Dammam Formations are unconformably overlain by sandstones of the Kuwait Group which include the Fars & Ghar Formations, again overlain by the Dibdibba Formation.
- The solid geology of the Greater Burgan site is located within the Fars & Ghar Formations with interbedded sands & clays, some sandstones & weak white nodular limestones
- Superficial deposits are predominantly Aeolian sands, with occasional gravels with sands, muds & calcareous sandstones

Investigation, Testing & Modelling

- Trial Pits determined the site specific geology & collected samples for both geotechnical & geochemical profiling
- Contaminated & uncontaminated sites in Al- Magwa sectors were chosen for more detailed investigation
- Both near surface (ground level), shallow (up to 0m) & deep (up to 2m) samples determined the critical zones for hosting potential contamination or problematic ground conditions
- Laboratory geotechnical tests were undertaken including Atterberg Limits, PSD analysis, permeability analysis & direct shear tests (where appropriate)
- Chemical testing primarily used Gas Chromatograph Mass Spectrometry (GCMS) to ascertain the nature of the residual hydrocarbons present together with elemental analysis
- Water soluble chlorides, sulphates & pH levels were tested
- GCMS enabled speciation of hydrocarbons present in order to determine the degradation that had taken place since the original spillages in 1991
- Human Health Exposure Assessment is being undertaken using RISC (Risk Integrated Software for Cleanups) software

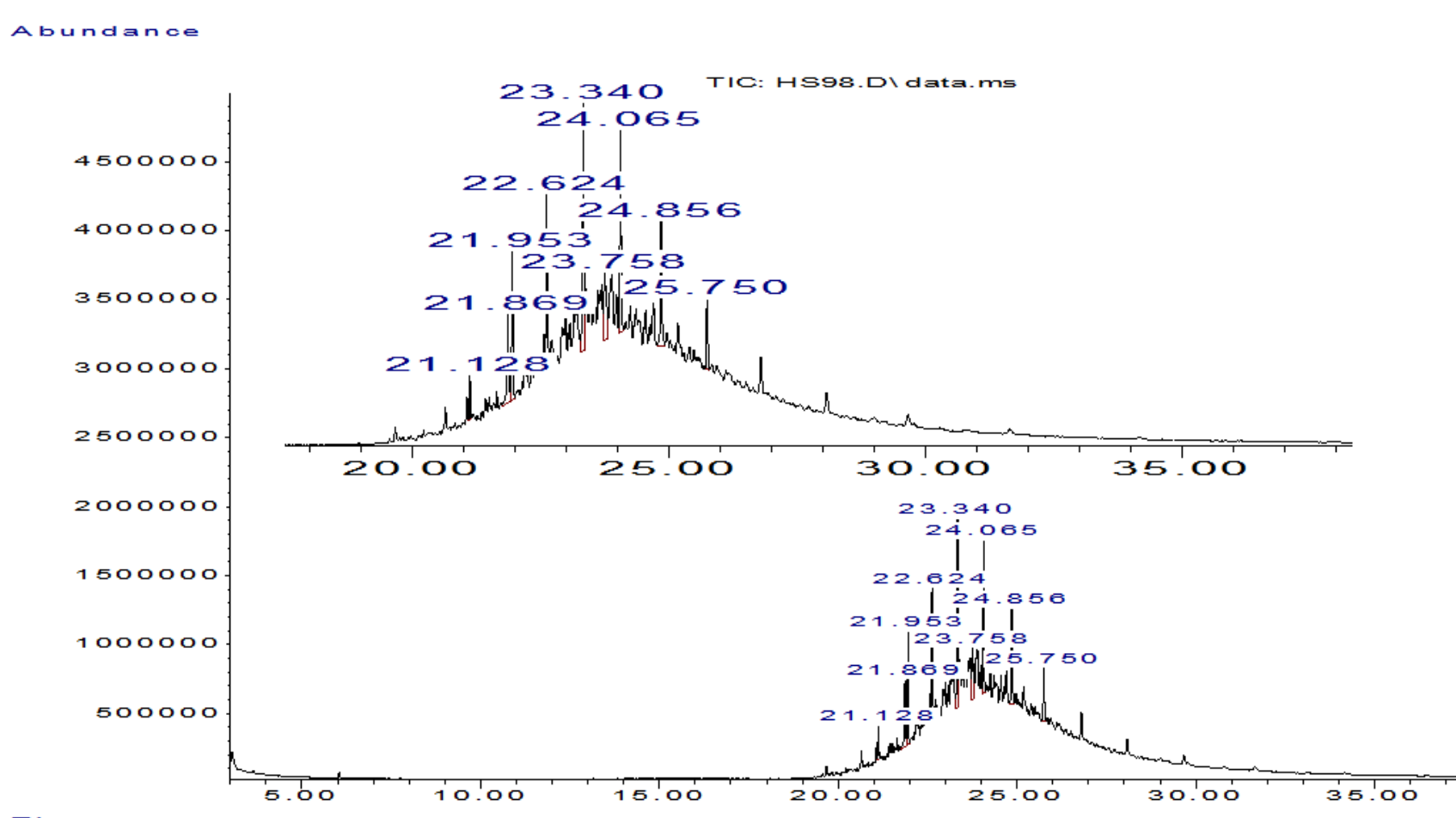


Fig 4. Chromatogram showing hydrocarbon contamination in the detected soil sample with Total Petroleum Hydrocarbons at depth 0m (ground surface), at a contaminated site in the Al-Magwa area.

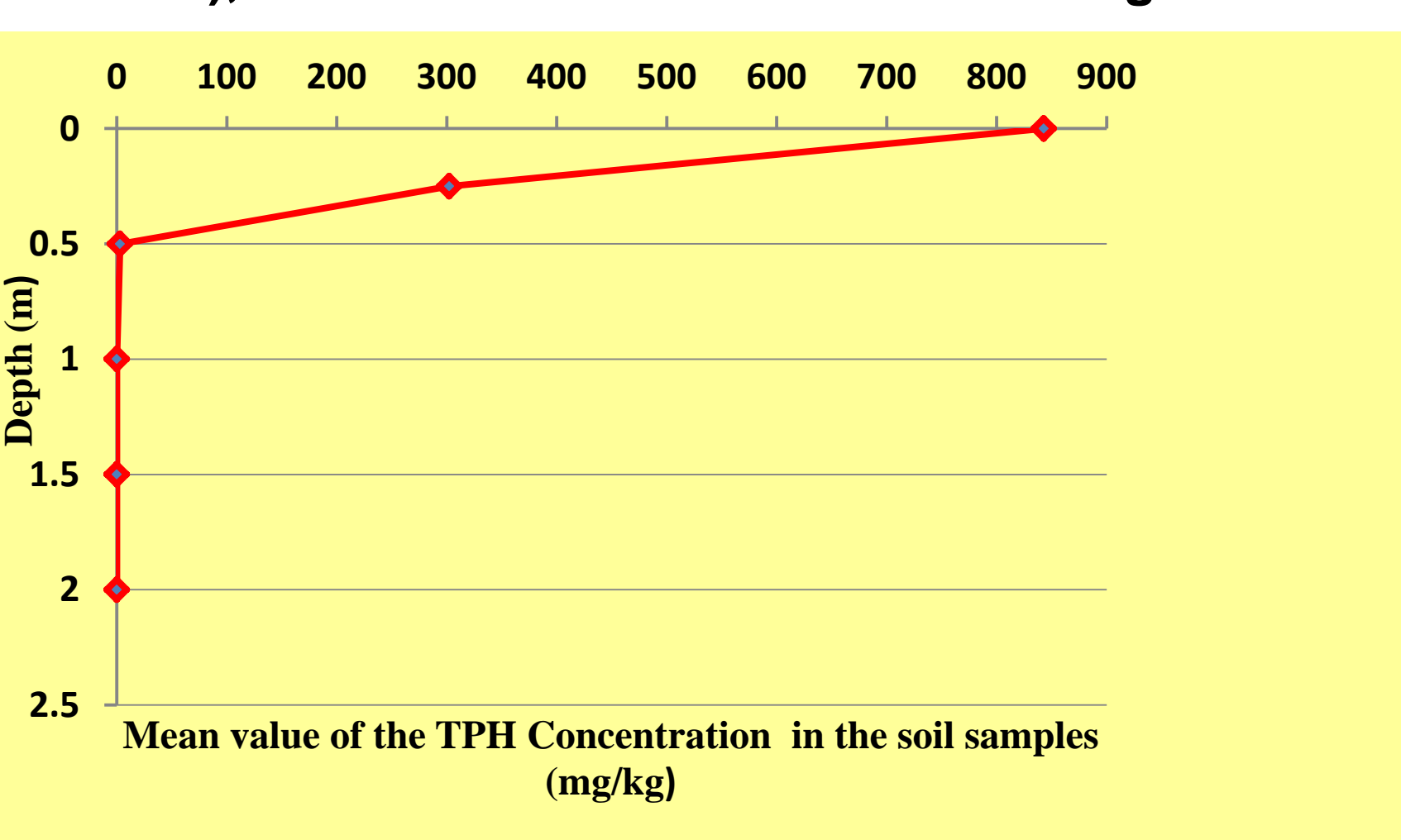


Fig 5. Mean value of the TPH concentration (mg/kg) in soil samples at depths 0.0m, 0.25m, 0.5m, 1.0m, 1.5m & 2.0m, Al-Magwa area.

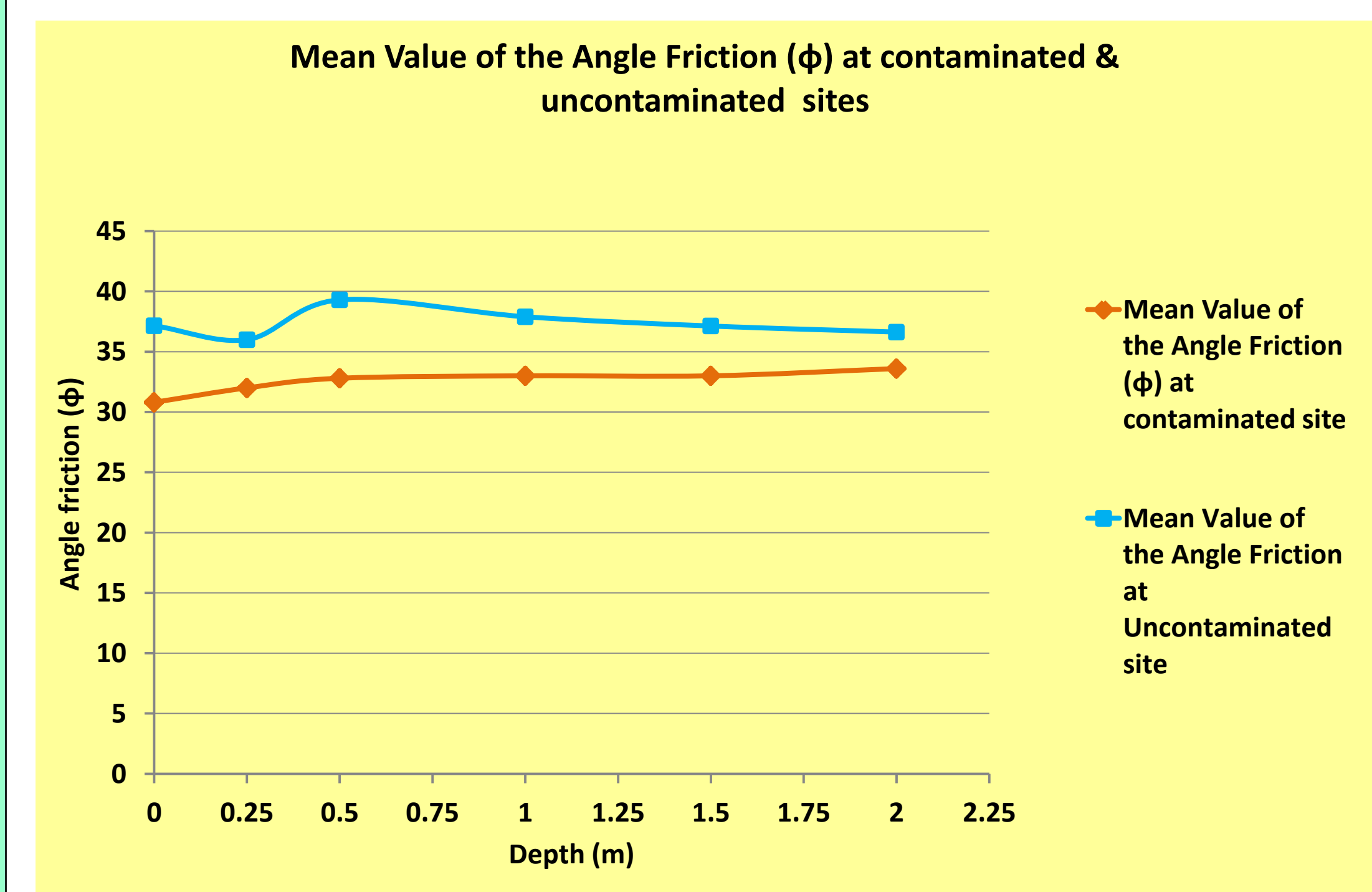


Fig 6 Comparison of the Mean Values of the Friction Angle (φ) from direct shear tests for soil samples at depths 0m, 0.25m, 0.5m, 1.0m, 1.5m & 2.0m at contaminated and uncontaminated sites in the Al-Magwa area.