Ziltek

# A Case Study on Kuwait Environmental Remediation Program

## RemScan Technology for Effective Contamination Management

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# Background

The Kuwait Environmental Remediation Program (KERP) is a significant initiative led by the United Nations Compensation Commission (UNCC), Kuwait National Focal Point (KNFP) and Kuwait Oil Company (KOC) to address the extensive environmental damage resulting from the Gulf War. The conflict left Kuwait's landscape heavily contaminated with oil, including wet and dry oil lakes, contaminated soil, and sludge, affecting an area of 114 square kilometers. This program, the largest of its kind, aims to remediate and restore the affected areas, focusing on both environmental and socio-economic rehabilitation. The comprehensive approach of KERP includes cleaning, remediating, and revegetating the impacted zones to restore ecological balance and support the well-being of future generations.

# Innovation in Soil Remediation

In the complex landscape of environmental remediation, Ziltek's RemScan technology offers a unique approach to soil hydrocarbon contamination assessment. RemScan, a state-of-the-art portable device, utilizes advanced mid-infrared (MIR) spectroscopy paired with proprietary software algorithms to provide rapid, in-field quantification of hydrocarbon levels in soil.

This technology improves on traditional methods, which often rely on extensive and time-consuming laboratory sample analysis. Instead, RemScan delivers rapid and accurate total petroleum hydrocarbon (TPH) contamination assessment directly in the field in under 20s, enabling quick decision-making and significantly speeding up the remediation process.

RemScan uses no consumables such as solvents for oil extraction, making its operation cost-effective and simple. This eliminates the need for operators to undertake solvent extractions in the field and avoids the logistical overheads of maintaining a constant supply of solvents. Operators do not need to continually calibrate the device as this is handled by Ziltek and their local representatives, ensuring sustained accuracy and reliability of the measurements.

Another key aspect of RemScan technology is Ziltek’s robust customer support framework and close collaboration with all contractors involved in the project to ensure the technology's optimal performance. This includes calibrating the device to suit the specific conditions of different zones, maintaining calibration integrity through a comprehensive quality control process, and conducting periodic quality control checks against laboratory measurements on samples.

RemScan was chosen as part of a competitive tendering process where many competing TPH field measurement technologies were trialed. Its superior performance and user-friendly design made it the preferred choice for the Kuwait Environmental Remediation Program (KERP).

The integration of RemScan into KERP highlights Ziltek's dedication to technological innovation and aligns with the program's goals of sustainability and ecological restoration by improving operational efficiency and reducing reliance on traditional laboratory methods, reducing operational expenses and accelerating project completion. This comprehensive support structure underpins Ziltek's commitment to deliver cutting-edge technology and ensure its effective application in large-scale remediation projects.

## KEY INDICATORS

| Indicator | Details |
|---|---|
| **RemScans Deployed** | 17 units |
| **Samples Analysed** | 10s of 1,000s soil samples |
| **Key Soils Identified** | 7 used for calibration standards |
| **Contamination Bands** | > 1% to ≤ 5%<br>> 5% to ≤ 7%<br>> 5% to ≤ 7%<br>> 7% to ≤ 10%<br>> 10% to ≤ 15%<br>> 15% |
| **Training Delivery** | Online streaming & on-site support |
| **Total Contaminated Area** | 114 square kilometers |
| **Soil Contamination Volume** | Approximately 26 million cubic meters |
| **Oil Lakes** | Wet and dry oil lakes as major features |
| **Soil Contamination Types** | Heavy oil contamination with various hydrocarbons |
| **Project Duration** | Scheduled for completion in 2027-2028 |
| **Total Budget** | About $3 billion (allocated by the UN) |
| **Funds Disbursed (as of 2023)** | Approximately $281 million of $1.73 billion |
| **Oil Recovery from Sludge** | Over 80% recoverable using centrifugation |
| **Remediation Techniques** | Excavation, bioremediation, oil sludge recovery |

# Challenges and Solutions

The implementation of KERP posed a series of complex and interlinked challenges that tested both Ziltek's technological capabilities and capacity for innovative problem-solving. The following are the primary challenges encountered and the corresponding solutions implemented:

## VAST AND COMPLEX CONTAMINATED AREAS

Spanning an extensive area of 114 square kilometers, the remediation efforts encompassed a wide range of geographic and geological diversity. The variety in terrain and soil types across the extensive contaminated landscape required an adaptable approach to remediation.

**Solution:** To manage the extensive and diverse contaminated areas, Ziltek provided custom, site-specific calibrations for each zone, accounting for unique lithologies. This involved:

1. Soil Survey: Collecting uncontaminated soil samples at regular intervals around the impacted areas to capture diverse soil types.
2. Spectral Analysis: Using mid-infrared (MIR) spectral analysis to identify soil composition variations.
3. Calibration Standards: Creating calibration standards by spiking key samples with known amounts of hydrocarbon standards, covering TPH content from 0 to 100,000 ppm.
4. Calibration Models: Developing precise models using spectral pre-processing algorithms and partial least squares (PLS) regression tailored for each zone.
5. Quality Control: Conducting regular quality checks and re-calibrations, cross-validating in-field measurements with lab results.

By deploying multiple RemScan units with these custom calibrations, Ziltek ensured accurate, real-time contamination assessments across the diverse remediation sites, enhancing the efficiency of KERP.

## HIGHLY COMPLEX CONTAMINANTS

The soil was contaminated with a multitude of complex petroleum hydrocarbons and their derivatives, a consequence of historical oil spills and wartime destruction. The crude oil on the surface is heavily weathered from exposure to the sun and elements, whereas the subsurface oil has been weathered to a different degree. This variation demanded a sophisticated approach to pollution identification.

**Solution:** RemScan addresses the challenge of identifying highly complex contaminants by directly measuring the total petroleum hydrocarbons (TPH) present in the soil from C10 upwards, without differentiating between different types of hydrocarbons. This capability simplifies the analysis process and ensures comprehensive contamination assessments. Key aspects include:

1. Direct Measurement: RemScan measures the TPH content in soil, providing a clear indication of contamination levels.
2. Quality Control: Regular quality control (QC) checks are performed to ensure the reliability of the results, particularly as the nature of the hydrocarbons changes throughout the project. This continuous monitoring helps maintain accuracy and consistency in the data provided.

By focusing on TPH measurement and maintaining rigorous QC processes, RemScan ensures accurate and reliable contamination assessments, streamlining the pollution treatment process and adapting to the evolving nature of the contaminants encountered.

## DEMAND FOR HIGH PRECISION AND REPRODUCIBILITY

Accurate identification and quantification of contaminants are crucial to the success of environmental remediation. Precision requirements for the technologies employed needed to be within 30% of the reference lab method, in line with field screening requirements. Additionally, measurement reproducibility had to be within 10% to ensure the efficacy and consistency of the remediation process.

**Solution:** To meet the precision requirements within 30% of the reference lab method and achieve measurement reproducibility within 10%, RemScan employed rigorous calibration and quality control processes. Key steps included:

1. Initial Calibration: Hundreds of uncontaminated soil samples were collected across the remediation zones, analyzed, and spiked with known concentrations of diesel fuel to create calibration standards covering TPH content from 0 to 100,000 ppm.

2. Advanced Algorithms: Custom spectral pre-processing algorithms and cascaded partial least squares (PLS) regression techniques were used to develop precise calibration models tailored for each specific zone.

3 Quality Control: Regular QC checks and re-calibrations ensured that the technology consistently met the high precision and reproducibility standards required for effective remediation.

RemScan technology is based on the state-of-the-art portable spectrometer platform TopScan 4300, manufactured by Agilent Technologies. This device is equipped with a Ziltek-designed sampling interface specifically made for soils, providing maximum signal strength even from highly absorbing materials like crude oil-contaminated soils. The combination of advanced hardware, tailored methods, precise calibrations, and ongoing support ensures the highest accuracy and reliability in contamination measurements.

## NECESSITY FOR REAL-TIME DECISION-MAKING

Given the complexity of the remediation tasks, the ability to make accurate and swift decisions was critical to the project's success. This required any technological solutions to not only provide precise data but also support the project team's decision-making processes in real time.

**Solution:** RemScan's capability to deliver immediate contamination data empowered project managers and field teams to make informed, real-time decisions. This was crucial for navigating the dynamic challenges of the remediation process. Key advantages include:

1. Rapid Data Availability: Scans take approximately 20 seconds, and results are displayed immediately on the screen. This rapid turnaround time allows for quick assessments and timely decision-making.

2. Cost-Effective Measurements: There is no additional materials or consumables cost to make additional measurements, enabling a more comprehensive understanding of contamination levels and their distribution. This enhances decision-making certainty without incurring significant additional costs.

3. Portability: RemScan units are fully portable and used on-site in real time, eliminating the need to wait for samples to be sent to a lab and for reports to be generated. This immediacy is essential for adaptive management, allowing teams to respond promptly to new contamination discoveries and adjust remediation strategies as needed.

By providing rapid, on-site contamination assessments, RemScan enhances the efficiency and effectiveness of the project, ensuring that remediation efforts are both timely and accurate.

## TECHNOLOGY ADAPTABILITY AND INNOVATION REQUIREMENT

The field screening technology needed to survive and be usable in the harsh environment of the Kuwaiti desert, with ambient temperatures exceeding 45°C and minimum daytime temperatures around 10°C during colder months. This adaptability was crucial for the technology to function effectively in extreme conditions.

**Solution:** Operating in the harsh Kuwaiti desert environment required robust and adaptable technology. RemScan units were specifically designed to meet these challenges, ensuring reliable performance throughout the project's duration. Key elements of this adaptability include:

1. Rugged Equipment: Both the RemScan device and the tablet computer (a rugged GETAC T800) are designed to operate in extreme conditions, from 0 to 60°C, and in dusty environments typical of the Kuwaiti desert. This ensures that the devices remain functional and reliable even under the most challenging conditions.

2. Field Kit Accessories: Our field kit accessories are designed to facilitate comprehensive field work, including sample collection and preparation, power management, charging, and instrument maintenance. These accessories enhance the ease and efficiency of using RemScan in the field.

3. Extended Operation: RemScan can operate away from power for over 8 hours at a time, making it highly suitable for long field days without the need for frequent recharging. This capability is crucial for maintaining continuous operations in remote locations.

4. Continuous Technological Innovation: Calibration methods are continuously revisited and updated to ensure that RemScan remains effective and accurate. This ongoing innovation is vital for adapting to evolving project requirements and environmental conditions.

5. Collaborative Improvement: Ziltek regularly meets with contractors and project managers to discuss potential technology improvements that can best facilitate operations. These meetings ensure that RemScan technology evolves in line with the needs of the project, providing practical solutions to emerging challenges.

6. On-the-Ground Support: Ziltek provides on-the-ground support through local representatives to ensure that maintenance and any required assistance are promptly available. This local support network is crucial for minimizing downtime and maintaining the effectiveness of RemScan units in the field.

By equipping RemScan with rugged, adaptable technology and ensuring it can operate effectively in extreme temperatures, Ziltek provided a reliable solution that met the challenging environmental demands of the KERP project. Continuous collaboration with project stakeholders and robust local support further enhances the technology's effectiveness and adaptability.

## ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS

The field screening technology needed to survive and be usable in the harsh environment of the Kuwaiti desert, with ambient temperatures exceeding 45°C and minimum daytime temperatures around 10°C during colder months. This adaptability was crucial for the technology to function effectively in extreme conditions.

1. Stakeholder Engagement: Ziltek staff made regular trips to Kuwait to meet with all contractors, the prime contractor, and the overseer, the Kuwait Oil Company (KOC). These meetings facilitated clear communication and collaboration, ensuring that the remediation efforts were well-coordinated and aligned with the project's objectives.

2. On-the-Ground Support: By providing on-the-ground support through local representatives, Ziltek ensured that maintenance and operational issues were promptly addressed. This support minimized downtime and disruptions, contributing to the overall efficiency and effectiveness of the remediation process.

3. Technological Contributions: The deployment of RemScan technology directly contributed to the accurate assessment and remediation of contaminated areas. By providing reliable, real-time data, RemScan allowed for informed decision-making, helping to restore contaminated land to a usable state more quickly and efficiently.

4. Training and Knowledge Transfer: Ziltek provided training to local contractors and project managers on the effective use of RemScan technology. This knowledge transfer ensured that local teams were equipped with the skills needed to operate the technology independently, fostering local capacity and sustainability.

By focusing on these specific contributions, Ziltek played a crucial role in addressing the environmental and socioeconomic challenges associated with KERP. These efforts not only advanced the project's goals but also supported the broader objective of sustainable environmental management in Kuwait.

# Application in KERP

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## SITE CHARACTERIZATION

During the initial stages of KERP, comprehensive site characterization is essential to understand the extent and nature of contamination. RemScan plays a crucial role in this phase by providing rapid, in-field assessment of hydrocarbon contamination levels. By deploying multiple RemScan units, field teams can cover large areas efficiently, collecting data that informs the development of site-specific remediation strategies. The ability to generate immediate results allows for real-time mapping of contamination hotspots, enabling a targeted approach to remediation efforts.

## EXCAVATION MONITORING

Excavation is a critical component of the remediation process, and monitoring hydrocarbon levels during this phase is vital to ensure that contaminated soil is properly managed. RemScan is used to continuously monitor the soil being excavated, providing instant feedback on contamination levels. This real-time data helps guide the excavation process, ensuring that only the necessary amount of soil is removed and preventing the unnecessary excavation of clean soil. The portability and rapid response time of RemScan are key advantages in maintaining efficient excavation operations.

## GRADING OF SOILS INTO CONTAMINATION BANDS

One of the innovative uses of RemScan in KERP is the grading of soils into contamination bands. This process involves categorizing soil based on contamination levels, allowing for differential treatment scenarios. Soils with higher contamination levels can be directed towards more intensive remediation processes, while soils with lower contamination levels can undergo less rigorous treatment. RemScan provides the precise, on-site measurements needed to accurately grade soils, facilitating a more efficient allocation of remediation resources.

# Application in KERP

## REMEDIATION BASELINE DETERMINATION

Establishing a baseline contamination level is essential before commencing active remediation. RemScan is employed to perform baseline assessments, providing a clear picture of the initial contamination levels across the site. This data serves as a reference point against which the success of remediation efforts can be measured. The precision and reliability of RemScan measurements ensure that the baseline data is accurate, forming a solid foundation for subsequent remediation activities.

## REMEDIATION PROCESS MONITORING

Throughout the remediation process, continuous monitoring is crucial to track progress and make necessary adjustments. RemScan is used to monitor the effectiveness of remediation treatments, providing immediate feedback on changes in hydrocarbon levels. This real-time data allows project managers to assess the efficacy of different remediation techniques and optimize them as needed. The ability to conduct frequent, cost-effective measurements enhances the overall responsiveness and adaptability of the remediation strategy.

## ASSESSMENT OF REMEDIATED SOILS

After remediation efforts have been completed, it is important to assess the final contamination levels to ensure that the soil meets the required environmental standards. RemScan is used to perform final assessments of remediated soils, verifying that hydrocarbon levels have been reduced to acceptable levels. The technology's high accuracy and reproducibility provide confidence in the assessment results, supporting the certification of remediated sites and their return to safe, productive use.

# Calibration and Recalibration Process

Ensuring the accuracy and reliability of RemScan's measurements involves rigorous calibration and periodic recalibration processes. These processes are crucial for maintaining high precision and consistency in assessing soil contamination levels.

## CALIBRATION PROCESS

The initial calibration of RemScan involves:

| Soil Sample Collection | Spectral Analysis |
|---|---|
| Gathering uncontaminated soil samples from various locations to capture a wide range of soil types. | Performing mid-infrared (MIR) spectral analysis on these samples. |
| **Creating Calibration Standards** | **Developing Models** |
| Spiking selected samples with known concentrations of diesel fuel to develop a range of TPH content standards. | Using custom spectral pre-processing algorithms and partial least squares (PLS) regression to create precise calibration models. |

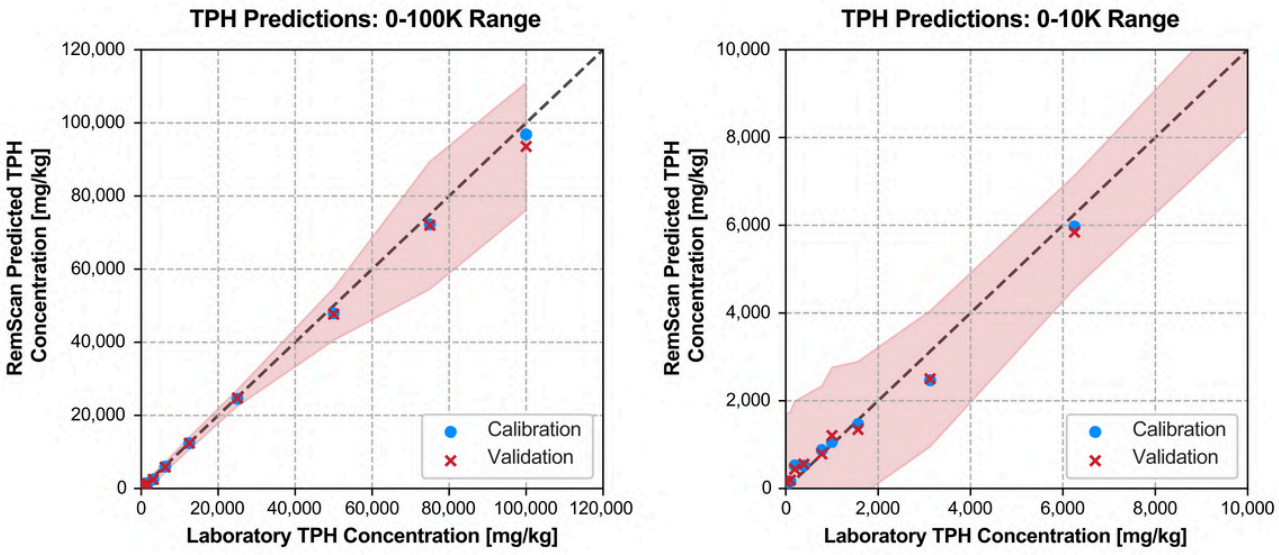


*Figure 1: Initial calibration results showing the correlation between actual and predicted TPH concentrations in soil samples.*

## QUALITY CONTROL AND RECALIBRATION

Regular QC checks compare RemScan's field measurements with laboratory reference results to identify any need for recalibration. When deviations are detected, the device undergoes recalibration to restore accuracy.

The recalibration process includes re-evaluating soil samples, adjusting calibration models based on new data, and validating these models with spiked samples to ensure accuracy.

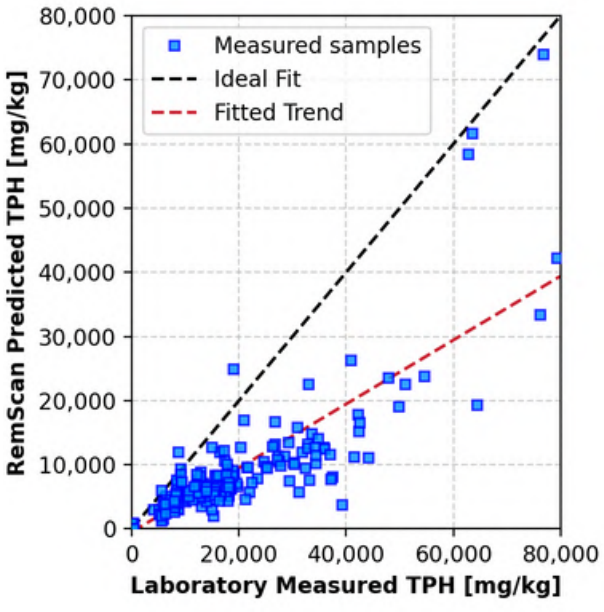


*Figure 2: QC data showing deviations in measurement accuracy, indicating the need for recalibration.*

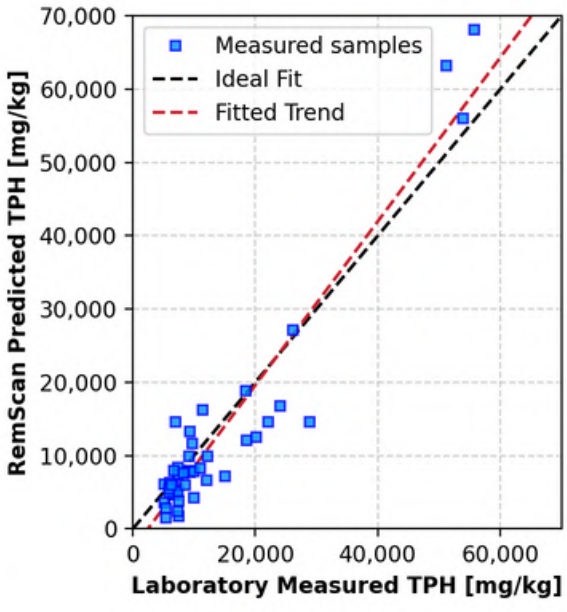


*Figure 3: Post-recalibration QC data showing improved correlation between RemScan measurements and laboratory reference values.*

# Conclusions

The Kuwait Environmental Remediation Program (KERP) is a massive effort to address the extensive environmental damage caused by the Gulf War. Through its comprehensive approach, KERP aims to restore the ecological balance and support the well-being of future generations by cleaning, remediating, and revegetating the impacted zones.

Ziltek's RemScan technology has proven to be an invaluable tool in this large-scale remediation project. By leveraging advanced mid-infrared (MIR) spectroscopy and proprietary calibration algorithms, RemScan provides rapid, in-field quantification of total petroleum hydrocarbon levels in soil. This capability has superseded traditional methods that rely on time-consuming laboratory analyses, enabling immediate and precise contamination assessments directly in the field. As a result, RemScan has accelerated the remediation process, enhanced operational efficiency, and reduced costs.

RemScan's integration into KERP has addressed numerous challenges, including the extensive and complex contaminated areas, highly complex contaminants, the demand for high precision and reproducibility, the necessity for real-time decision-making, and the need for technology adaptability in harsh environmental conditions. Through custom calibrations, rigorous quality control, continuous technological innovation, and robust customer support, Ziltek has ensured the reliable performance of RemScan throughout the project's duration.

Furthermore, Ziltek's contributions have extended beyond technological innovation to include substantial support in stakeholder engagement, on-the-ground assistance, and training and knowledge transfer. These efforts have not only advanced KERP's environmental goals but also supported the broader objective of sustainable environmental management in Kuwait.

Ziltek's RemScan technology has demonstrated its unique value and effectiveness in the Kuwait Environmental Remediation Program. By providing accurate, real-time contamination assessments and maintaining high standards of precision and reliability, RemScan has played a pivotal role in the success of KERP. Ziltek's commitment to delivering cutting-edge technology and comprehensive support underscores its dedication to environmental stewardship and sustainable remediation practices, making a lasting impact on Kuwait's natural landscape and communities.

# Get in Touch

Connect with us for detailed insights into our technologies and projects.

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