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Capabilities of Industrial Waste Management Services Providers in the Western Region of Saudi Arabia

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Abstract

This article examines circular treatment capabilities relevant to industrial waste management in Jeddah, Rabigh, and Yanbu. Circular treatment is defined as a process or treatment sequence that achieves verifiable material recovery, water reuse, or reduced disposal volumes through recovery and reuse. Drawing on site visits and technical literature, the article considers treatment options for oily wastewater, oily sludge, contaminated soil, and hazardous chemical residues. These include wastewater treatment, centrifugation, bioremediation, soil washing, chemical and thermal treatment, and engineered disposal. The site visits provide regional context, while the literature explains process functions and applications. Effective resource recovery depends on understanding the incoming waste, selecting compatible treatment steps, and confirming the quality and destination of each output. Opportunities include improving connections between existing processes, strengthening source segregation and operator skills, and assessing additional technologies for specific waste streams. Controlled disposal remains necessary for non-recoverable residues.

Keywords

Industrial Waste Management, Circular Economy, Resource Recovery, Saudi Arabia

1. Introduction

Industrial waste generators produce diverse waste streams, including oil, solvents, spent acids, alkalis, and metal-bearing residues. Properties such as toxicity, flammability, reactivity, and corrosivity influence handling and treatment requirements (Kingdom of Saudi Arabia, 2021). Waste management services providers bring the equipment and expertise needed to manage these streams safely and re-

cover useful materials where possible.

This article focuses on Jeddah, Rabigh, and Yanbu in western Saudi Arabia, with particular attention to oily wastewater, sludge, contaminated soil, and chemical residues. Effective management requires complementary treatment processes and clear destinations for recovered products and remaining wastes. The National Waste Management Strategy sets a target to divert 89% of industrial waste from landfills by 2040, as reported in the National Center for Waste Management (MWAN) guidelines for sorting industrial waste at source (National Center for Waste Management, 2025). Strengthening recovery and reuse capabilities in the Western Region can support progress toward this national target.

1.1. Circularity Criteria

Treatment contributes to circularity when it produces materials suitable for an approved use, water that meets reuse requirements, or lower disposal volumes through recovery. Classification depends on the output and its actual destination. The same equipment may support recovery at one facility and prepare waste for disposal at another.

Dewatering, neutralization, stabilization, and landfilling do not constitute recycling on their own, although they may support a wider recovery sequence or reduce hazards. Energy recovery should be recorded separately from material recycling. Verification requires input and output measurements, quality checks, confirmed destinations, and accounting for secondary wastes. Disposal volumes should be compared consistently so that water removal is not mistaken for material recovery. Table 1 summarizes the circular potential of the treatment options discussed in Section 3.

Table 1. Treatment options and conditions for circular outcomes.

Treatment option	Potential contribution to circularity	Checks and residual management
Wastewater treatment	Oil recovery and water reuse when the outputs meet requirements for their approved use.	Check oil and water quality and confirm reuse; manage sludge and concentrate.
Centrifugation and sludge processing	Separation of recoverable oil, with water recovery through further treatment.	Account for each separated stream; dewatering alone is not recycling.
Bioremediation and soil washing	Reuse of suitable treated soil or soil fractions, reducing disposal volumes.	Check cleanup and reuse criteria; manage contaminated fines, wash water, and leachate.
Chemical treatment	Preparation for a documented recovery or reuse step later in the process.	Check reaction products and residues; neutralization alone is not recovery.
Thermal desorption	Recovery of suitable condensates or reuse of treated soil where demonstrated.	Check output quality; treat off-gas and manage remaining contamination.
Incineration	Possible energy recovery, recorded separately from material recycling.	Confirm useful energy output; control emissions and manage ash and other residues.
Stabilization and engineered landfilling	Hazard control and residual disposal; neither is resource recovery on its own.	Check waste acceptance and containment; beneficial use requires separate approval.

Source: Authors' synthesis of Pinasseau et al. (2018), the Federal Remediation Technologies Roundtable (FRTR, n.d.-a, n.d.-b, n.d.-d, n.d.-e), and Neuwahl et al. (2019). These outcomes depend on the waste, operating conditions, output quality, and approved recovery or reuse destination.

2. The Role of Waste Management Services Providers

The information presented in this article is based on site visits to Reviva's Yanbu and Rabigh facilities, Gulf Elite, Environmental Horizons, Sustainable Environmental Works, and Arabian FEAL. Information gathered during these visits is supported by technical literature explaining the treatment processes. Reviva's published information on its regional locations and oil and water recovery services provides additional context (Reviva, n.d.-a, n.d.-b).

Saudi Arabia's Waste Management Law requires waste management activities to be licensed or permitted by the National Center for Waste Management (MWAN) and addresses recovery, reuse, segregation, and safe disposal (Kingdom of Saudi Arabia, 2021). Each project must meet applicable Saudi requirements and facility approvals; international guidance informs technical decisions but does not replace these obligations.

A reliable service begins with waste characterization, segregation, compatibility assessment, and controlled reception (Pinasseau et al., 2018). These checks determine the appropriate recovery, treatment, or disposal route. Planning must also address the separated oil, sludge, wash water, membrane concentrate, and ash produced during treatment.

3. Treatment Options and Their Industrial Applications

The following sections explain treatment options relevant to the region's industrial wastes, drawing on the site visits described in Section 2 and technical literature. Process selection depends on the incoming waste and the required recovery, reuse, discharge, or disposal outcome. Thermal desorption is included as a potential service option; its availability at a particular regional facility requires confirmation. The numerical criteria below define selected output requirements and benchmarks; they are not reported performance results for the facilities visited.

3.1. Industrial Wastewater Treatment

Industrial wastewater treatment manages oily liquids and aqueous process wastes, including centrifuge centrate and condensates. Operators should confirm compatibility and treatability before accepting each stream, particularly where it differs from the normal feed. Treatment combines physical, chemical, and, where appropriate, biological processes to meet the required effluent quality (Pinasseau et al., 2018).

3.1.1. Equalization and Oil and Water Separation

Equalization tanks balance variations in flow and pollutant load. Skimmers and gravity separators remove free oil, supporting recovery and reducing the load on downstream units. Common separators include American Petroleum Institute (API) separators and corrugated plate interceptors (CPI). Stable emulsions and dissolved contaminants require additional treatment (Pinasseau et al., 2018).

3.1.2. Flotation

Dissolved air flotation (DAF), or dissolved nitrogen flotation where appropriate, uses fine bubbles to carry dispersed oil and suspended solids to the surface for removal. Coagulation or emulsion breaking can improve separation of material remaining after gravity treatment (Pinasseau et al., 2018).

3.1.3. Biological Treatment

Biological treatment can take several forms. A membrane bioreactor (MBR) combines biological treatment with membranes that separate biomass from treated water (U.S. Environmental Protection Agency [U.S. EPA], 2007). In a moving-bed biofilm reactor (MBBR), microorganisms grow on mobile carriers, with separate downstream solids removal where needed (Levstek & Plazl, 2009). Choosing between these systems requires an understanding of the waste's biodegradability and any substances that may inhibit microbial activity. Highly saline or toxic streams need specific assessment before acceptance.

3.1.4. Membrane Polishing

Reverse osmosis (RO) reduces dissolved salts, producing permeate and a concentrated reject stream. Performance depends on feed quality, membrane selection, and operating conditions. Pretreatment controls fouling and scaling, while the concentrate requires appropriate management (U.S. EPA, n.d.). RO should be selected for a defined water-quality objective.

3.1.5. Post-Treatment Water Quality

Post-treatment testing must reflect the discharge or reuse route. **Table 2** gives selected Saudi limits for treated wastewater discharged to coastal and marine waters (Ministry of Environment, Water and Agriculture [MEWA], n.d.). Sewer discharge and water reuse require their own acceptance criteria. The full applicable requirements and permit conditions, including Royal Commission requirements where relevant, determine the monitoring scope.

Table 2. Selected Saudi limits for treated wastewater discharged to coastal and marine waters.

Parameter	30-day average limit	Limit for any sample
pH	—	6.5 - 9.0
Total suspended solids (TSS), mg/L	25	40
Five-day biochemical oxygen demand (BOD_5), mg/L	10	25
Chemical oxygen demand (COD), mg/L	20	50
Total extractable fat, oil and grease (FOG), mg/L	—	2
Dissolved oxygen (DO), mg/L	—	Minimum 2

Source: MEWA (n.d.), Appendix 2. Limits are maxima except for the pH range and minimum DO. A dash means no 30-day average is listed here. This is a selected parameter set; nutrients, metals, phenols, microbiological indicators, and other applicable requirements must also be assessed.

3.2. Centrifugation and Sludge Management

Centrifuges separate mixtures of oil, water, and solids, reducing handling volumes and preparing streams for recovery or further treatment. Their compact footprint and continuous operation can be useful, although energy use, wear, maintenance, and conditioning requirements affect suitability (U.S. EPA, 2000).

Equipment and chemical conditioning should be tested with representative feed; municipal-sludge performance figures cannot be assumed to apply to industrial residues. Separated oil must be checked for recovery suitability, centrate needs wastewater treatment, and dewatered solids require further treatment or authorized disposal. Dewatering does not remove all hazardous properties (Pinasseau et al., 2018; U.S. EPA, 2000).

For recovered oil, a provisional basic sediment and water (BS&W) target of ≤0.5% by volume can be used for evaluation, subject to the receiving refinery's written specification. As an international commercial example, Bakken Pipeline Company LP's 2016 tariff limits basic sediment, water, and other impurities collectively to 0.5%, including no more than 0.3% free water (Bakken Pipeline Company LP, 2016). This is not a Saudi statutory limit or evidence that centrifugation alone achieves that quality.

3.3. Bioremediation of Contaminated Soil

Bioremediation uses microbial activity to treat biodegradable organic contaminants in soil. Landfarming involves spreading and periodically mixing material, while biopiles provide more controlled aeration of excavated soil. Performance depends on contaminant bioavailability, oxygen, moisture, nutrients, and temperature (FRTR, n.d.-a, n.d.-c).

Hot, dry conditions require careful moisture and temperature management. Treatment areas need containment and controls for runoff, leachate, dust, and relevant vapors. Sampling must confirm that cleanup criteria have been met before reuse or disposal. Bioremediation does not degrade metals and is unsuitable for some organic contaminants, so mixed contamination may need additional treatment (FRTR, n.d.-a).

Total petroleum hydrocarbon (TPH) content is used here to assess contamination in soil and solids. Bioremediation should continue until the soil meets its approved reuse criteria. **Table 3** gives Saudi petroleum-hydrocarbon fraction limits for coarse topsoil under industrial land use. These limits also guide soil washing and thermal desorption for the same reuse destination; other soil types, depths, and land uses require the corresponding standards (MEWA, n.d.).

3.4. Soil Washing

Soil washing separates contaminated fines from coarser material or transfers contaminants into water, reducing the volume requiring intensive treatment or disposal. It generally suits soils with substantial sand and gravel fractions better than fine-grained soils. Performance depends on particle size, contaminant association

with the soil, and washing chemistry (FRTR, n.d.-d).

Table 3. Saudi petroleum-hydrocarbon limits for coarse topsoil under industrial land use.

Petroleum-hydrocarbon fraction	Maximum concentration in soil, mg/kg
F1: C6 to C10	270
F2: C10 to C16	260
F3: C16 to C34	1700
F4: C34 to C50	3300

Source: MEWA (n.d.), Appendix 1, p. 12. Test each carbon range against its own limit; do not add the limits to create a single allowable TPH concentration. Also meet requirements for benzene, toluene, ethylbenzene and xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), metals, and the approved reuse destination.

After screening and characterization, soil is mixed with water and, where treatability testing supports their use, additives. Agitation releases fines and contaminants from coarser particles, which are then separated. Wash water is treated and recirculated where feasible. Reuse requires confirmation that the recovered soil meets its approved destination's criteria; contaminated fines and water-treatment residues still need treatment or disposal (FRTR, n.d.-d).

Washed sand intended for industrial topsoil reuse would meet each petroleum-hydrocarbon fraction limit in **Table 3** (MEWA, n.d.). Verification should cover the recovered sand separately from the contaminated fines.

Water quantities depend on the washing circuit. For a Kuwait oil-contaminated-soil project, CDE (2025) reports 2 metric tonnes of wash water per metric tonne of soil, equivalent to approximately 2 m^3/t using a water density of 1000 kg/m^3, with a design recycling rate of up to 90%. This is a gross wash-water requirement requiring treatment and recycling, not a measured net wastewater-discharge rate. The source does not specify a dry-soil basis. A net wastewater quantity per tonne of contaminated sand must therefore be established from the plant water balance, accounting for recycling, rinsing, water retained in soil and fines, and evaporation. Purged wash water and dewatering drainage require controlled collection and treatment or authorized disposal (CDE, 2025; FRTR, n.d.-d).

3.5. Chemical Treatment and Neutralization

Chemical treatment is used for spent acids, alkalis, and certain metal-bearing liquid wastes. Neutralization adjusts pH, while metals may need precipitation followed by solids separation. These steps can prepare a compatible waste stream for further treatment or authorized disposal (Pinasseau et al., 2018).

Testing should establish reagent demand, reaction behavior, and residual quality. Safe operation depends on controlled dosing, mixing, temperature monitoring, and containment. Adjusting pH alone does not necessarily destroy organic contaminants, remove dissolved metals, or make waste non-hazardous. The treated

output must meet the receiving process or disposal facility's requirements (Pinasseau et al., 2018).

3.6. Thermal Treatment and Industrial Waste Incineration

Thermal desorption heats soil or sludge to transfer volatile and semivolatile contaminants into an off-gas stream that must be captured and treated. Incineration destroys suitable organic constituents through combustion. Neither process should be assumed to eliminate metal contamination (FRTR, n.d.-b). Thermal desorption is considered here as a potential service option, subject to confirmation of installation, licensing, and availability at the intended facility.

For thermally desorbed soil intended for industrial topsoil reuse, the treatment target is compliance with every fraction limit in **Table 3**, together with other applicable contaminant criteria (MEWA, n.d.). Where a desorption system recovers oil by condensation, the provisional BS&W target is ≤0.5% by volume, subject to the receiver's specification and the qualifications in Section 3.2 (Bakken Pipeline Company LP, 2016; ASTM International, 2022). Further separation may be needed. These targets concern desorbed soil and recovered condensate, not incinerator ash.

Incineration performance depends on feed composition, temperature, residence time, mixing, and oxygen availability. Temperature alone cannot guarantee destruction of every hazardous constituent. Flue-gas cleaning, emissions monitoring, and management of bottom ash and air-pollution-control residues are essential (Neuwahl et al., 2019).

Energy recovery may be practical where the feed is suitable and there is a use for the heat or power produced. Benefits should be weighed against energy demand and environmental controls, with energy recovery reported separately from material recycling. Ash and other residues require characterization and authorized treatment or disposal (FRTR, n.d.-b; Neuwahl et al., 2019).

3.7. Stabilization and Engineered Landfilling

Stabilization reduces contaminant mobility through chemical reactions, while solidification changes physical properties, often by adding a binder. Reagent selection should reflect the waste's leachability, durability, and handling requirements. These processes can prepare non-recoverable residues for controlled disposal (FRTR, n.d.-e).

Acceptance must follow applicable Saudi requirements and the receiving facility's authorization. The Toxicity Characteristic Leaching Procedure (TCLP), U.S. EPA Method 1311, measures contaminant leachability (U.S. EPA, 1992). **Table 4** lists selected concentration limits from MWAN's publicly available waste-classification guidance; the same values appear in the U.S. toxicity-characteristic regulation, 40 CFR 261.24 (National Center for Waste Management, 2023; U.S. EPA, 2026).

Table 4. Selected TCLP concentration limits for waste characterization.

Contaminant	TCLP extract concentration, mg/L
Arsenic	5.0
Barium	100
Cadmium	1.0
Chromium	5.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0
Benzene	0.5

Sources: National Center for Waste Management (2023), Appendix 3; U.S. EPA (2026), Table 1. These are extract concentrations, not total concentrations in the solid. Under 40 CFR 261.24, a result equal to or above a listed value triggers the toxicity characteristic.

Where treatment aims to meet these leachability thresholds, results should be below the applicable value for each relevant constituent, allowing for analytical and waste variability. The table is not exhaustive. Passing these selected tests alone does not establish that waste is non-hazardous, suitable for reuse, or acceptable at a particular landfill; other hazardous properties and the facility's acceptance conditions still apply (National Center for Waste Management, 2023; U.S. EPA, 2026).

Engineered hazardous-waste landfills require containment and long-term management, including liners, leachate collection, leak detection, runoff control, groundwater monitoring, and closure and post-closure care (U.S. EPA, 2014). Design must account for local geology and hydrogeology, waste characteristics, and regulatory requirements. Disposal capacity should be planned alongside upstream recovery and treatment.

4. Regional Opportunities and Capability Development

4.1. Opportunities for Resource Recovery and Integrated Services

A practical opportunity is to connect existing processes so that separated oil, treated water, and suitable soil fractions can be recovered or reused. Reviva's reported waste treatment and oil and water recovery services illustrate this direction in the region (Reviva, n.d.-a, n.d.-b). Site-visit information provides a basis for assessing improvements within existing operations.

Additional technologies, including cavitation-based approaches and thermal desorption, merit waste-specific assessment. Investment should depend on demonstrated recovery or reuse, secondary-waste requirements, costs, and regulatory approvals. Their inclusion here does not establish whether they are deployed elsewhere in Saudi Arabia.

Mobile units may support incident response, reduce transport needs, or provide temporary capacity where site conditions and approvals allow. International guidance describes mobile or portable soil washing and thermal treatment systems (FRTR, n.d.-b, n.d.-d). Project assessments should consider mobilization, utilities, containment, emissions controls, and residual management before estimating savings.

4.2. Operational Considerations for Reliable Service Delivery

Service selection should consider variable waste composition and volumes, operating costs, specialist staffing, transport distances, and outlets for recovered products. Waste management services providers should demonstrate performance across the treatment sequence, supported by sampling, maintenance, and contingency arrangements. Clear information on installed equipment, licensed activities, and available capacity helps customers select a suitable service.

5. Conclusion

Waste management services providers can help the Western Region's industries recover resources and manage residual wastes safely. Site visits and technical literature show the value of considering wastewater treatment, oil recovery, sludge processing, soil remediation, chemical and thermal treatment, and disposal as connected services. The appropriate combination depends on the incoming waste and the quality required for each recovered product or final residue. These capabilities can help advance the national target of diverting 89% of industrial waste from landfills by 2040 (National Center for Waste Management, 2025).

The next step is to strengthen recovery and reuse within these treatment systems. Better waste characterization, source segregation, operator skills, and reliable destinations for recovered products can improve existing services and inform investment in additional capacity. Progress should be measured through verified material recovery and water reuse, while recognizing that reducing waste volume or hazards alone is not recycling. Controlled disposal remains necessary for residues that cannot be recovered.

Author Contributions

Both authors developed the concept for the article, conducted site visits, collected information, and reviewed the technical literature. Both authors contributed to drafting, reviewing, and editing the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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