Review Paper

STUDY OF REHABILITATION ON PLANT SPECIES OVER REMEDIATED SOILS IN KUWAIT DESERT ENVIRONMENT

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ABSTRACT

This project is intended to Study on Rehabilitation of Plant Species over Remediated Soils in Kuwait Desert Environment. The general goal of the Remediation & rehabilitation component of the project was to leave areas of the oil fields, such as effluent pits, sludge pits and gatch pits that were contaminated, in a relative natural state such that once completed, the areas would not require ongoing management and would not cause adverse impacts elsewhere through drifting sand and contaminated aquifers. To this end, the rehabilitation component of the project included a native plant restoration and monitoring program with the purpose to evaluate the effectiveness of restoration methods, namely the use of irrigation and soil amendment, in facilitating the establishment of a native plant community. In addition, it was thought that if the remediated (cleaned) soil was returned to the various pits and native plants could be established, that would also be a good indicator of the success of the soil remediation process.

Components of the rehabilitation program included eight native plants, high-level and low-level irrigation and soil amendment (biogenic fertilizer). Plants were installed in the features using a block design whereby equal numbers of plants received the irrigation and soil amendment treatments, as applicable. In the reference area blocks, half of all plants received high-level irrigation and the other half received low-level irrigation. In the gatch pits, all plants received high level irrigation. In sludge and effluent pits, half of the blocks were established in amended soil and the other half were established in unamended soil. Within the blocks, half of all plants received high-level irrigation and the other half received low-level irrigation. Plant survival, growth, soil moisture, salinity and temperature were measured over the 18 month monitoring period.

Keywords: Rehabilitation, Remediation, Soil amendments etc.

INTRODUCTION TO ECOLOGY OF KUWAIT DESERT

The Kuwait environment consists of a relatively flat coastal plain with little topographic relief. It is characterized by very hot summers and cool winters. The majority of the rainfall occurs in the winter months. Three major terrestrial plant communities occur in Kuwait, in the north the community is dominated by Haloxylon salicornicum, in much of the rest of Kuwait by Rhanterium epapposum, and in the south eastern region by Cyperus conglomeratus (Omar et al. 2001). The majority (70%) of plant species are annuals and they result in a significant greening of the desert in the late winter and early spring months, after which they die back and even the perennials may lose their leaves and become dormant during the hot dry summer months.

Desert ecosystems are fragile and are highly susceptible to the impacts of compaction and grazing (Al-Awadi et al. 2005, Brown 2003, Brown and Schoknecht 2001). Compaction is caused by vehicles and domestic animals and while a single pass by a vehicle may not be injurious to the soil and vegetation, repeated passes and the creation of compacted

soil layers has a major deleterious impact on the functioning ecosystem (Adams et al. 1982). Prior to the development of the oil fields, the majority of compaction occurred due to the presence of domestic grazing animals such as camels, goats and sheep. Prior to the Gulf War, domestic animals had access to the areas of the oil fields that are now enclosed by protective fencing. As a consequence, the vegetation that was once sparse in the oil fields has exhibited a considerable amount of growth and recovery. However the damage from decades of compaction and overgrazing is still very evident.

The operations of the oil fields have changed significantly during the past 70 years, but over the decades, hydrocarbons and other waste generated from operations have been intentionally and unintentionally deposited in pits and piles throughout the oil fields. High levels of hydrocarbons in the soils have inhibited plant growth and the present project is concerned with the remediation and rehabilitation of representative sites in the Burgan oil field specifically.

Drifting sand is considered a major problem in Kuwait and the loss of vegetation in the desert and sub-desert only exacerbates the situation. Sand is blown in the direction of the prevailing wind, which is from the north-west.

AIM & OBJECTIVE OF THE STUDY

The rehabilitation program was designed to measure the effectiveness of the remediation processes used by the consortia engaged to remediate effluent pits, sludge pits and gatch pits in the Burgan Oil Field. It was thought that if the remediated (cleaned) soil was returned to the various pits and native plants could be established that would be a good indicator of the success of the remediation and that there was a restoration of the desert ecosystem at these sites. Discussions about the advantages of planting established nursery grown plants versus seeding resulted in the conclusion that for the purposes of evaluation of the effectiveness of the remediation program, established plants grown in nurseries would be preferable as their success and growth rate could be better measured than the germination and survival of seedlings grown directly in-situ.

Some plants are capable of growing in heavily contaminated soils and during the field surveys shrubs and grasses growing directly adjacent to or on oil contaminated soils were examined. The ability of plants to grow in such conditions is also related to the degree of soil compaction, salinity and the hydrophobic nature of the soil. If the soil particles are not uniformly coated with oils, and the salinity levels are not too high, then there is the potential for water to penetrate the soil and plants to grow.

A number of plants were proposed for the Rehabilitation Program and it was thought that in order to simplify the program, a maximum of five species (two shrubs, one grass, one sedge and one legume) would be used in the sludge and effluent pits and an additional three tree species in the gatch pits. The species selected for the Rehabilitation Program are all native Kuwaiti species and were: Rhanterium epapposum, Nitraria retusa, Panicum turgidum, Cyperus conglomeratus, Astragalus spinosus, Ziziphus spina-christi, Acacia gerrardii and Prosopis farcta.

METHODOLOGIES IMPLEMENTED

Literature Search on Recent Desert Restoration:

A literature review on desert remediation and rehabilitation was undertaken that included talking to researchers in Kuwait, as well as online research of peer reviewed and gray literature.

Plant Species Selection:

Plant selection for the rehabilitation of remediated sites was based on using

a few perennial species that are native to Kuwait. It was essential to use perennials as otherwise the success of the plantings could not be evaluated. The majority (70%) of native Kuwait plants are annuals (Omar et al. 2007), limiting the choice of potentially suitable plant species. It was thought to be most practical to have two shrubs, two grasses and a legume. The choice of the Rhanterium epapposum was obvious, as it is the national flower of Kuwait. This species also forms the dominant plant community in Kuwait, is important in sand stabilization, and is the preferred species for grazers (Omar and Bhat 2008). The second shrub chosen was Nitraria retusa which is common in coastal and saline soils and should do better in some of the more saline soils found in and around oil field operations. The most common sedge species is undoubtedly Cyperus conglomeratus, which forms dominant plant communities in south east Kuwait and is widespread in sand formations in many phytogeographic regions of Arabia (Batanouny 1987, Omar et al. 2007). It is very hardy and it was thought to be a good choice for planting in potentially unstable disturbed areas, which was the expected condition of the remediated sites. A grass, Panicum turgidum, was chosen because it is one of the dominant grasses in Kuwait, forming distinct mounds of considerable size (Batanouny 1987). The choice of a legume was difficult as the majority of legumes are annuals. However, Astragalus spinosus was selected because it is a perennial species, it has large spines that would protect it from grazers and was thought to be suitable as a potential nitrogen fixer in conditions that are known to be nitrogen deficient. While there appears to be little information about the use of native legumes in Kuwait to improve soil conditions, many authors have found that various species are very effective at fixing atmospheric nitrogen and contributing to improved soils under desert conditions (Al-Fredan 2010, Weiwei 2002).

Lastly, it was decided to plant native tree species as well in the gatch pits and three species; Acacia gerrardii, Prosopis farcta and Ziziphus spina-christi, were selected. It was recommended that small groves of trees be planted at several locations within the gatch pits to provide an opportunity for birds to use them for roosting, nesting and feeding. The trees also provide seeds that are of value to other wildlife.

Irrigation Design:

In order to provide a measured amount of water to plants, a system using two different diameter PVC pipes (10 cm and 7.5 cm), each 50 cm long and capped with a PVC cap at the bottom end, was utilized. Five holes 3 millimeters (mm) in diameter were drilled at 7.5 centimeters (cm) intervals up one side of each pipe. The pipes were sunk 45 cm into the ground and were removed at the conclusion of the irrigation phase. Larger diameter tubes provided 3.92 litres of irrigation water (i.e. high level irrigation) and smaller diameter tubes provided 2.2 litres of irrigation water (i.e. low level irrigation) during each irrigation event. The top of the PVC pipe was covered in a wire mesh screen to prevent animals falling in the pipes. A pair of larger holes was drilled near the top of each tube to allow a rod to be slipped through for extraction of the tube should maintenance be required.

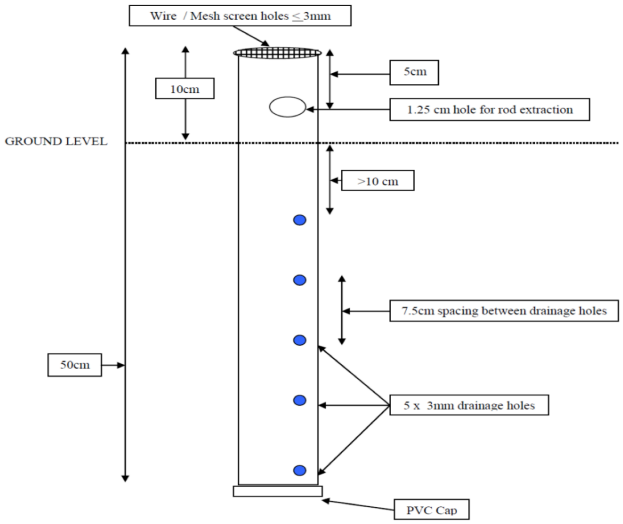

Figure: Irrigation Design

The normal precipitation in Kuwait falls irregularly in the winter months from October to May with most of the

precipitation falling in December and January (Batanouny 1987, Brown 2002). During this period plants may grow, flower and reproduce. Once the late spring and summer temperatures occur, native plants either die or go into dormancy. It was therefore decided to limit the irrigation of plants to the winter and spring months to help them become established. Irrigation was applied twice monthly from November to May regardless of natural rainfall patterns, and ceased during the hot summer months when the plants normally senesce or go into dormancy. Such an irrigation regime was also found to be effective by nursery growers in Kuwait (Kaitharath pers com).

Planting Time:

The intent for specifying a definite window for planting was the necessity to give plants time to establish themselves prior to the hot summers when they would not have any water.

Therefore, the earliest time in the winter is preferable and a recommended time from November to mid- December was thought to be optimal for plant establishment. This would give plants approximately four months to develop root mass and sufficient reserves to survive the summer dry period. However, in some instances the timing of plant installation was extended into subsequent months due to the delay in site preparation activities and availability of plant material.

Planting Layout:

Reference Areas: The layout of the reference areas was defined in the contract specifications Technical Specification Part III: Materials and Workmanship, Planting Procedures and Site Layouts. Reference blocks were 24 m x 24 m with plants spaced at 2 m on centres (o.c.) resulting in a total of 144 plants. Plants were installed in a replicating pattern of shrub 1 (R. epapposum), legume (A. spinosus), grass 1 (P. turgidum), shrub 2 (N. retusa), legume (A. spinosus), grass 2 (C. conglomeratus). Prior to installation, all plant material was inspected for general good health and as per QA/QC requirements. After the plants passed inspection, they were planted adjacent to the previously installed irrigation tubes. Half of the plants received low level irrigation and the other half received high level irrigation. Plants were watered in-situ after they were installed and the irrigation tubes were also filled for the first watering.

Gatch Pits: Four gatch pits were identified for remediation, three were identified for rehabilitation planting after waste removal and site stabilization (Technical Specification Part III: Materials and Workmanship, Planting Procedures and Site Layout). Planting occurred between December and February to allow plants time to become established prior to summer dormancy. The contractors were to provide planting in 30% of the permitted planting areas, in a number of blocks to allow colonization of the rest of the gatch pits. The number of planting blocks and number of plants installed varied depending on the pit feature 0 for details on planting blocks). However, across all features, plants were installed in a replicating pattern of shrub 1 (R. epapposum), legume (A. spinosus), grass 1 (P. turgidum), shrub 2 (N. retusa), legume (A. spinosus), grass 2 (C. conglomeratus). Due to problems with growing A. spinosus in the nurseries, either a substitute species was permitted (e.g. Z. spina-christi) or the quantities of the other four species were increased. Prior to installation, all plant material was inspected for general good health and as per QA/QC requirements. After the plants passed inspection, they were planted adjacent to the previously installed irrigation tubes. All irrigation tubes in the gatch pits were high volume. Plants were watered in-situ after they were installed and the irrigation tubes were also filled for the first watering.

Sludge and Effluent Pits: Upon completion of soil remediation six planting blocks were laid out in each pit

feature. In the sludge pits, the blocks were a dimension of 24 m x 24 m and in the effluent pits, the blocks were a dimension of 48 m x 48 m. A soil amendment was applied in half of the planting blocks Planting occurred between December and early-March. Plants were installed in all pits in a replicating pattern of shrub 1 (R. epapposum), grass 2 (C. conglomeratus), legume (P. farcta), shrub 2 (N. retusa), grass 1 (P. turgidum), and legume (P. farcta). Prior to installation, all plant material was inspected for general good health and as per QA/QC requirements. After the plants passed inspection, they were planted adjacent to the previously installed irrigation tubes. Half of the plants received low level irrigation and the other half received high level irrigation per each block. Plants were watered in-situ after they were installed and the irrigation tubes were also filled for the first watering.

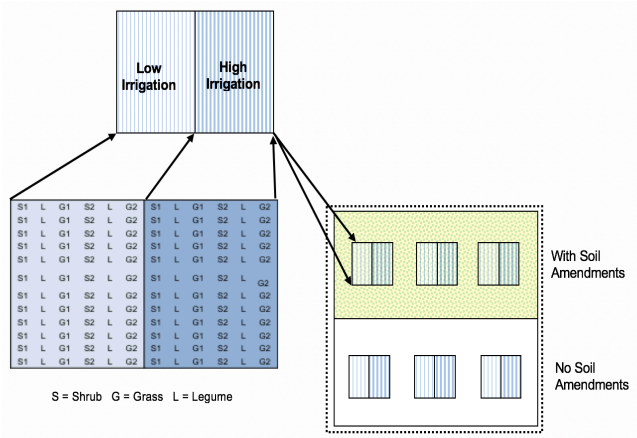

Figure: Planting Blocks Layout

Soil Remediation Technologies and Standards:

Soil remediation technologies utilized in the project included soil washing, thermal desorption and bioremediation. Three sludge pits and six effluent pits were identified for testing these processes and their potential effects on restoration outcomes. The objective of the remediation was to obtain materials with remaining contamination achieving or falling below the thresholds identified.

RESULTS

Plant survivorship in remediated soils at the end of experiment period: 56%. Plant growth and survivorship in remediated areas slightly lower than in not contaminated soils in Control Areas and Gatch Pits; Soil amendments do not significantly improve plants' growth and survivorship; Rehabilitation improves re-settlement of natural plants and wild-life.

LESSONS LEARNT AND CONCLUSIONS

Soil amendments have not significantly improved plants' survivorship compared to areas with no amendments applied. Soil amendments have not made any difference in plants' survivorship compared to areas with no amendments applied. Soil amendments significantly deteriorated plants' survivorship. No need to adopt soil amendments in future projects.

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