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Vegetation and Management of Tar Piles on Qatar Coastal Marshes

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ABSTRACT. This pilot study was decided to assess the problem of oil pollution in Qatar and other oil producing countries and suggest a management programme for disposing the collected tar or lessening the impact of tar pile accumulation by using flowering plant indicators. The vegetation in the dumping sites of tar and other sea-borne materials is used in field survey as bioindicator of tar pollution and natural recovery of polluted sites. The phytomonitoring results indicated that recovery of polluted landscape can be quite rapid under managed clean-up and restoration techniques. The following preliminary plant species list is suggested to be used in natural recovery and restoration of polluted sites: *Aeloropus lagopoides, Aizoon canariense, Anabasis setifera, Cyperus conglomeratus, Fagonia ovalifolia, Herniaria hemistemon, Launaea procumbens, Oligomeris subulata, Reichardia tingtana, Salsola baryosma, Schanginia aegyptiaca, Senecio desfontainei, Zygophllum quatarense* and *Zygophyllum simplex*. To facilitate natural plant invasion and restoration of tar piles, the dumping sites must have plant communities with high species diversity and high percentage of annual plants. Depending on sand-tar ratio in the piles, artificial seeding of selected plant species can be applied by using species mixes or single species seeding. Management considerations are suggested to optimize the natural recovery and restoration of tar affected coastal marshes.

Introduction

Arabian Gulf region is of interest and concern to many, and that the subject of exploration and exploitation for oil and natural gas is an emotionally explosive topic in terms of economics and environment. For all member Gulf states, the beaches and the coastal and marine environments are becoming increasingly important in fulfilling social, economic development and strategic objectives. Yet, there has been difficulty in translating such concern into meaningful or practical modus operandi.

Most of the Qatari shores have had a long history of oil pollution. Crude oil reaches the coasts from exploratory and production wells, refineries, oilfield blow-outs, tanker and pipeline break-ups, industrial discharge and leaking from oily deposits (Price, 1993). The crude oil and other sea-borne materials reaching the shore are deposited along the coastline. Most of these deposites show profiles in which 1-3 layers of tar reflect the history of oil spills and deposites. Layers of deposited tar some few centimeters to 30 cm thick, about 1-6 meters wide can be found along the coastline.

Over the past decade, attempts have been made to remove the deposited tar on beaches and dump it few hundred meters away from the shoreline as packed piles in the coastal marshes. This way of dumping has expanded the problem rather than solving it, as the amounts of tar piles are progressively increasing. The tar piles and the physical disturbances associated with the clean-up activities are of great threat to the natural landscape and the environment in the coastal ecosystems. Hirtherto, effects on ecosystem structure and function are generally not well known.

The purposes of this pilot study are to: (1) assess the impact of tar pile accumulation and monitor its colonization by wild flowering plants, and (2) suggest management considerations for lessening the impact of tar pile accumulation by using flowering plant indicators.

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Study Area

The study sites no. I, II, III, and IV are located from north of Al-Zubarah to Ruwais along the northern western coast of Qatar (Fig. 1). The structural geology has been described by Cavelier (1970). The landscape is almost flat, gravely and pebbly, showing often hardly marked depressions in which silt and clay accumulated. Various types of limestone of marine origin extend along or close to the coastline. Sandy deposites of varied extent are localized along the coastline and also at the edge or within the coastal marshes.

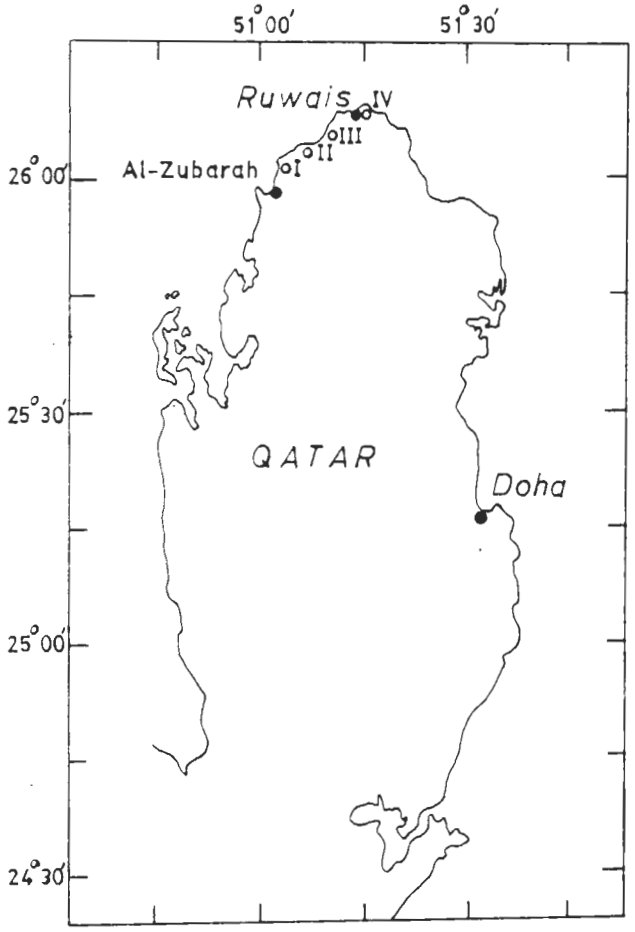

FIG. 1. Study area and location map of the study sites (O) no. I, II, III and IV.

Materials and Methods

For clean-up operations, the deposited tar on the coastline was bladed or stripped and dumped in the coastal marshes in the form of dome-shaped piles. The average height of the pile ranges between 1 and 2 m with base circumference of 8-12 m. During stripping, the tar is usually mixed with some of the coastal sediments. Tar content of piles varies and ranges from about 10-90% (v/v). Considering the tar content, the piles were grouped into four classes; less than 25%, 25-50%, 50-75%, and more than 75% tar content. The age of tar piles was determined from the date of cleaning time and their dumping in the coastal marshes.

Vegetation studies were carried out on both tar piles and their surrounding plant communities. Plant species were grouped into different life-forms according to the location of perennating buds (Raunkiaer, 1934). These included phanerophytes, chamaephytes, hemicryptophytes, geophytes and therophytes. Quadrats sampling method was applied. The sum of the relative density, relative cover and relative frequency gave the importance value of different species in the studied sites (*cf.* Kent and Coker, 1992).

The Berger-Parker index (Berger and Parker, 1970) is employed to determine whether there is any difference in plant species diversity in both tar piles and their surrounding plant communities. The index was calculated from the importance value using the following equation: $d = I_{max}/I$. Where I = total importance value of individuals, and I_{max} = importance value in the most important species, (*i.e.* species with highest importance value). In order to ensure that the index increases with increasing diversity, the reciprocal form 1/d of the measure is usually adopted.

Soil sampling and analysis was carried out following Allen *et al.* (1974).

Results

Soil

The properties of soil in the tar piles and dumping sites that support the natural plant communities are shown in Table 1. The soil texture is formed mainly of fine sand and coarse sand. The silt and clay are relatively low with values less than 10% of the soil physical components. The soils are slightly alkaline in reaction with higher pH values in the dumping sites than in tar piles. The soil salinity in the dumping sites ranged from 1300 ppm to 3150 ppm, compared with 600 to 860 ppm in the tar piles of sites I and IV, respectively. In general, the soil salinity in the dumping sites reveal higher values than that in tar piles.

Vegetation

The overall number of major plant species recorded in the four study sites are 27 species belong to five different life-forms (Table 2). Comparison of life-form spectrum based on the species list indicates the dominance of chamaephytes and therophytes over the other life-forms. The phanerophytes are the least life-form represented in the study sites, while hemicryptophytes and geophytes are modestly represented.

The recorded plant species are distinguished into

TABLE 1. Soil properties in tar piles and dumping sites supporting the natural plant communities.

Soil factors	Site							
	I		II		III		IV	
	tar pile	community	tar pile	community	tar pile	community	tar pile	community
Coarse sand (%)	36	27	34	39	21	23	27	32
Fine sand (%)	57	62	61	54	74	70	62	56
Silt (%)	4	6	2	3	3	5	8	3
Clay (%)	3	5	3	4	2	2	4	2
pH value	7.2	7.8	7.6	8.1	7.1	7.8	7.2	7.6
Salinity (ppm)	600	1300	750	3200	710	2800	860	3150

TABLE 2. The major plant species recorded in the study sites and their presence/absence on tar piles and surrounding communities. Age of tar piles = 6 years, percentage of tar in piles = 25-50%, (Ph = Phanerophyte, Ch = Chamaephytes, He = Hemicryptophytes, G = Geophytes, Th = Therophytes).

Plant species	Life form	Site							
		I		II		III		IV	
		tar pile	community	tar pile	community	tar pile	community	tar pile	community
Acacia tortilis	Ph	–	+	–	+	–	–	–	–
Aeloropus lagopoides	G	+	+	+	+	+	+	+	+
Aizoon canariense	Th	+	–	–	–	–	–	–	–
Anabasis setifera	Ch	+	+	+	+	–	–	+	+
Atriplex leucoclada	Ch	–	+	–	+	+	+	–	–
Cressa cretica	G, He	+	+	–	–	–	–	–	–
Cyperus conglomeratus	G	–	–	–	–	+	+	+	+
Fagonia ovalifolia	Ch	–	–	+	+	+	+	–	–
Frankenia pulverulenta	Th	–	–	–	–	+	+	–	–
Glossonema edule	Ch, He	–	–	–	+	–	–	–	–
Halopeplis perfoliata	Ch	–	–	–	–	–	–	–	+
Helianthemum lippii	Ch	–	–	–	–	–	+	–	–
Helianthemum kahiricum	Ch	–	–	–	+	–	–	–	–
Herniaria hemistemon	He	–	–	–	–	–	–	+	–
Launaea procumbens	He	+	+	+	+	+	–	–	–
Limonium axillare	Ch	–	+	–	–	+	+	+	+
Lycium shawii	Ph	–	–	–	+	–	–	–	–
Mesembryanthemum nodiflorum	Th	–	–	+	+	–	–	–	

TABLE 2. Contd.

Plant species	Life form	Site							
		I		II		III		IV	
		tar pile	community	tar pile	community	tar pile	community	tar pile	community
Oligomeris subulata	Th, He	–	–	+	+	+	+	–	–
Reichardia tingtana	Th	+	+	+	+	–	–	–	–
Salsola baryosma	Th, Ch	+	+	+	+	+	–	+	+
Senecio desfontainei	Th	–	–	–	–	+	–	–	–
Schanginia aegyptiaca	Th	+	+	+	+	+	+	+	+
Sporobolus arabicus	G	–	–	+	+	+	+	–	+
Suaeda vermiculata	Ph, Ch	–	–	–	–	–	–	–	+
Zygophyllum quatarense	Ch	+	+	+	+	+	+	+	+
Zygopyllum simplex	Th	+	+	+	+	+	+	–	–

three major groups according to their ability to invade or colonize the tar piles :

(1) The species recorded in the surrounding plant communities and successfully colonized the tar piles include *Aeloropus lagopoides, Anabasis setifera, Cyperus conglomeratus, Fagonia ovalifolia, Launaea procumbens, Oligomeris subulata, Reichardia tingtana, Salsola baryosma, Schanginia aegyptiaca, Zygophyllum quatarense* and *Zygophyllum simplex*. These species are expected to tolerate or endure high levels of tar pollution.

(2) The species recorded in the surrounding plant communities and did not colonize the tar piles include *Acacia tortilis, Glossonema edule, Halopeplis perfoliata, Helianthemum lippii, Helianthemum kahiricum, Lycium shawii* and *Suaeda vermiculata*. These species are expected to be sensitive and highly affected by tar pollutants.

(3) The species not recorded in the surrounding plant communities and colonized the tar piles include *Aizoon canariense, Herniaria hemistemon* and *Senecio desfontainei*. These species seem to be invaded by the tar piles from remote plant communities, and are expected to be highly tolerant for tar pollution.

This botanical survey reveals that coastal flowering plants can conveniently be used as tools for phytomonitoring of crude oil or tar pollution in the Arabian Gulf region. The tolerant species can also be used in restoration of tar polluted coastal marshes, while sensitive species may serve as bioindicators.

Species Diversity

The variation of species diversity in tar piles and their surrounding plant communities in the four study sites are shown in Fig. 2. Tar piles in site II exhibit higher diversity than in surrounding plant communities. In the other three sites I, III and IV, the surrounding plant communities attained higher diversity than in the tar piles. The diversity index of tar piles in the study sites ranged between 1.89 and 4.1 in site IV and II respectively. While the surrounding plant communities, showed an increase from 3.1 in site I to 6.3 in site IV.

Considering the tar content, the diversity index significantly decreases with increasing the tar content of the piles (Fig. 3). A wide range of stability in diversity over tar content from 25 to 75% in piles was observed. However, the trends are similar for all study sites investigated.

When the age of tar pile is considered (Fig. 4), the highest diversity index of tar piles for different ages occurs at site II with values ranged between 1.5 and 6.8 for age of 2 and 14 years, respectively. The remaining three sites with highest diversity index are, in descending order, sites IV, III and I. In general, the pattern of species diversity of tar piles is increasing with age of the pile at the different study sites.

Discussion

The Qatari coastlines are dynamic environments, with their physical habitats be seen as a battleground between sand and sea currents. The majority of the coast is characterized by sea current-driven sand transport. When these sands are mixed with the crude oil spills and reaches onshore, most of the volatile frac-

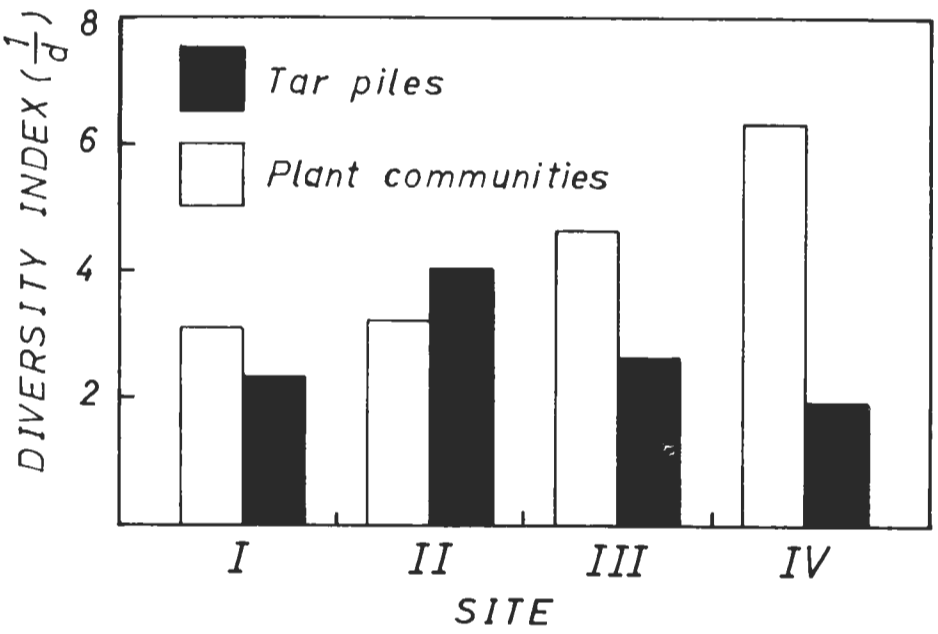

FIG. 2. Plant species diversity index in the tar piles and surrounding plant communities in the different study sites.

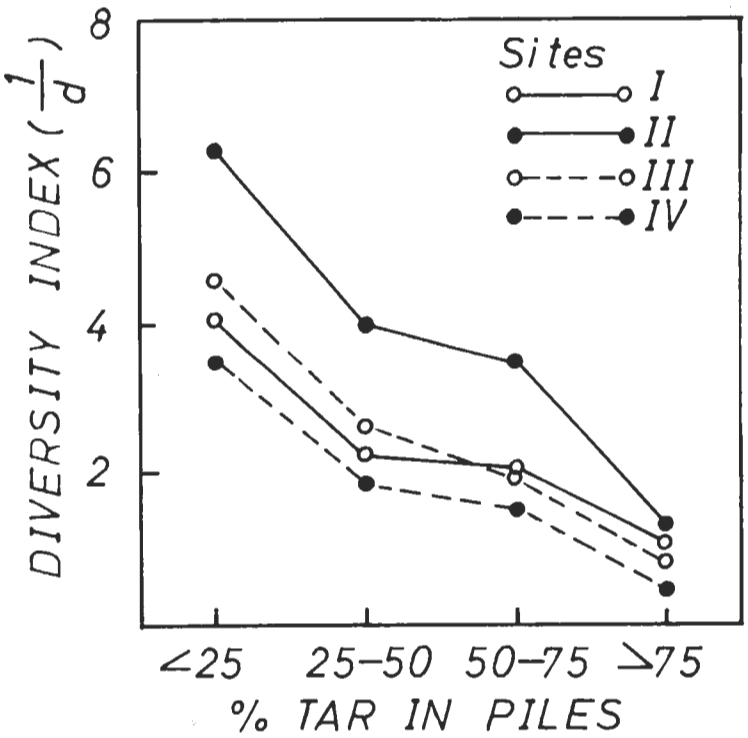

FIG. 3. Variation of plant species diversity with tar content of piles in the four study sites.

tion evaporates, thus increasing the viscosity and making it immobile tar mats. Blading or stripping of tar mats or oil saturated sand into piles in the coastal marshes is followed by colonization of the piles by wild flowering plants. The colonizing plant species seem to fasten the recovery and vegetation recruitment on tar piles changing it into naturally-looking landscape within few years.

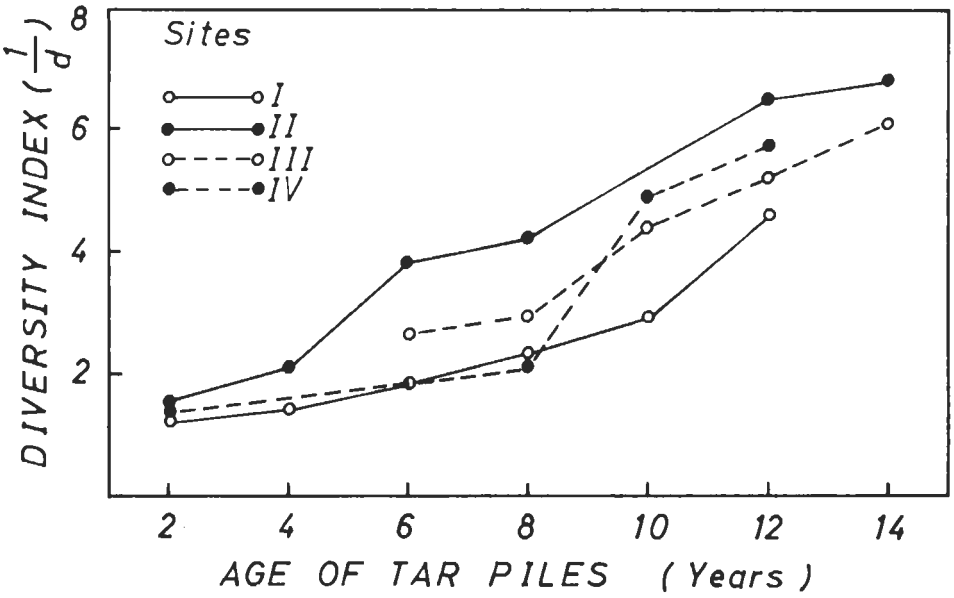

FIG. 4. Variation of plant species diversity with the age of tar piles in the different sites.

The successful colonization of tar piles by some plant species associated with flourishing and increased plant diversity in some sites may subsequently induce local increased diversity of associated fauna, which in turn help the natural recovery of coastal ecosystems polluted by tar. Studies conducted in other regions have shown that not all crude oils or their specific components are equally phytotoxic (Baker, 1970). This can be true in the Arabian Gulf region as our results indicated the increase of plant diversity in one of the study sites or facilitated plant invasion of tar piles when compared with the surrounding natural plant communities in the coastal marshes. The studies of Huston (1979) and Cody and Diamond (1975) suggested that plant species diversity may be related to disturbance. These studies predicted that diversity rise and then fall as disturbance rate increases, with maximum diversity occurring at an intermediate level of disturbance. This can be explained by habitat heterogeneity, resource partitioning and competition, and niche partitioning (Grubb, 1977; Tilman, 1982).

The plant response to crude oil or tar toxicity varies according to species and degree of habitat disturbance during cleaning-up activities (Carthy and Arthur, 1968; Burns and Teal, 1979). Plant growth may either increase or decrease where polluted sediments may have long-term implications on growth and survival beyond simple toxicity to plants. Under the arid environment of the Gulf region, recovery of tar affected areas is faster in tar piles with less tar content that are dumped in more diverse sites, that facilitates plant invasion from the surrounding plant communities.

Restoration of accumulated tar piles in the Qatari coastal marshes can be accomplished by using the successful plant colonizers of tar piles. Meanwhile, the microsite differences in tar piles due to variation of its tar content and age, will favour establishment of different species in different microsites. However, further investigations on the biological characteristics, ecological tolerances and suitability for revegetation of the tar pile plant colonizers are needed. Such investigations will help in choice of the suitable species for restoration of tar polluted areas.

Management Considerations

The future of coastal crude oil pollution is not one of the gloom and doom. Although, pollution by crude oil is not an easy environmental problem, there are signs of solving it by using new techniques that will cut across the traditional methods of handling tar pollution along the coastal ecosystems of oil producing countries. The successful establishment and colonization of tar piles of some wild flowering plant species is encouraging indicator of using plants in the future restoration programmes. This will aid in the development of coastal land use practices as well as land use regulations.

The following considerations are required to put forward management strategy for tar pile accumulation in the coastal ecosystems :

(1) Establishment of coastal dumping sites in regions that have widespread occurrence of massive oil accumulation. These sites are preferred to be near by a

more diverse natural plant communities and in areas not be in high demand for urgent land uses.

(2) Immediate blading or stripping of oil saturated sand into piles in selected sites in the coastal marshes is encouraged.

(3) Mixing of tar with suitable amounts of the beach sand before dumping in trenches or landfills of suitable size and depth. This procedure will fasten the natural recovery of tar piles into natural landscape.

(4) Re-vegetation of tar piles can be accomplished by using the successful natural plant colonizers. Reseeding must be completed very early in the growing season to take advantage of the winter rain. Seed mixes of different species and life-forms are preferred because of the microsite differences in the piles as a result of heterogeneous mixing of tar, sand and seaborne materials. Suitable fertility treatments may give good plant growth and fast establishment.

(5) Detailed investigations of short-term and long-term effects, ecological consequences and accumulation of oil-related contaminants on coastal wildlife (flora and fauna) under arid environments of the Gulf are needed. However, very little is known about the fate of the oil in plants, animals and the food chains.

(6) One of the obvious way for increasing the rate of tar pile decompositions and clean-up is to apply some microbiological inoculation mechanisms that may fasten the natural recovery of tar dumping sites and improve the flowering plant establishment and growth.

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References

Allen, S.E., Grimshaw, H.M., Parkinson, J.A. and **Quarmby, C.H.** (1974) *Chemical Analysis of Ecological Materials*. Oxford, Blackwell, 565 p.

Baker, J.M. (1970) The effects of oils on plants. *Environmental Pollution*, **1:** 27-44.

Berger, W.H. and **Parker, F.L.** (1970) Diversity of planktonic foraminifera in deep sea sediments. *Science*, **168:** 1345-1347.

Burns, K.A. and **Teal, J.M.** (1979) The west falmouth oil spill: hydrocarbons in the salt marsh ecosystem. Estuarine coastal. *Marine Science*, **8:** 349-360.

Carthy, J.D. and **Arthur, D.R.** (1968) *The biological effects of oil pollution on littoral communities*. Field Studies Council, London. 198 p.

Cavelier, C. (1970) *Geological Description of the Qatar Peninsula*. Government of Qatar, Department of Petroleum Affairs. 30 p.

Cody, M.L. and **Diamond, J.M.** (eds) (1975) *Ecology and Evolution of Communities*. Harvard University Press, 545 p.

Grubb, P.J. (1975) The maintenance of species-richness in plant communities. The importance of the regeneration niche. *Biological Review*, **52:** 107-145.

Huston, M. (1979) A general hypothesis of species diversity. *American Naturalist*, **113:** 81-101.

Kent, M. and **Coker, P.** (1992) *Vegetation Description and Analysis: A Practical Approach*. Belhaven Press, London, 363 p.

Price, A.R.G. (1993) The Gulf: Human impacts and management initiatives. *Marine Pollution Bulletin*, **27:** 17-27.

Raunkiaer, C. (1934) *The Life Forms of Plants and Statistical Plant Geography*. Oxford, Clarendon Press.

Tilman, D. (1982) *Resource Competition and Community Structure*. Princeton University Press, 296 p.

الكساء النباتى وإدارة أكوام القار على السواحل القطرية

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المستخلص: تعانى السواحل القطرية شأنها شأن الدول المنتجة للنفط من مشكلة التلوث النفطي الناتج من مصادر مختلفة. وعادة يتم تجميع القار من على الشواطىء ويلقى به فى أماكن قريبة على طول الساحل. وقد أجريت هذه الدراسة الأولية لتقييم المشكلة واقتراح بعض التوصيات للتخلص من أكوام القار المتراكمة على السواحل القطرية. استخدمت النباتات الزهرية المكونة للكساء النباتى فى المناطق الساحلية ككواشف نباتية للتلوث النفطى. وقد بينت الدراسة أنه يمكن استخدام النباتات الزهرية في إعادة تأهيل المناطق المتأثرة بالتلوث النفطى وذلك عن طريق التخلص من القار المتراكم على الشاطىء بعد تجميعه فى أماكن ذات مواصفات بيئية معينة. وقد تم اقتراح قائمة لعدة أنواع نباتية يمكن استخدامها في برامج إعادة تأهيل الشواطىء الملوثة بأكوام القار إلى حالتها الطبيعية.