ARTICLES

Environmental Impact Assessment of the Gulf War

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Abstract:

The environment of Kuwait has been severely disrupted by the military operations and the oil well fires during the different phases of the Gulf war (1990 - 1991). The main objective of the present study is to qualitatively assess the environmental impact of the Gulf war. The matrix system is applied. In this matrix, the main activities are tabulated against the environmental parameters. Scoring from 10 to zero was used to reflect the magnitude of the potential impact and its importance. Scoring was based on the experience of specialists of different fields, i.e., geology, plant ecology, soils, hydrogeology, biology, air pollution, and meteorology. The activities during different phases of the Gulf war were quantified using the information on the Iraqi war machinery and fortifications, satellite images before and after the Gulf war and intensive field survey. The present study reveals that the liberation phase activities inflicted the most adverse environmental impact on the environment, whereas the activities during the pre-invasion phase had the lowest environmental impact. Moreover, the oil fires and their consequences had the greatest impact on the environmental elements. Land parameters were highly affected by the different activities. The south-

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western area is the most severely damaged area. The main cause of damage was the oil well fires and their consequences and military operations. The north-eastern area, which contains vital water resources, followed in the rate of damage. Both military operations and oil well fires and consequences damaged this area. The western and northwestern areas affected by military operations follow in the degree of damage.

General

Following the environmental disaster caused by the Iraqi invasion of Kuwait and Gulf war to liberate Kuwait, an intensive study was carried out jointly between the Kuwait Institute for Scientific Research and Boston University to assess the damage of the war activity on the environment (Al-Ajmi et al. 1994). This paper presents the methodology and results of the Environmental Impact Assessment (EIA) section of this study. The results and findings of other sections of the study, such as the remote sensing and field survey have been used in the EIA. However, the methodology and actual results are not discussed. Only one paper has been published, so far, from this study, related to the remote sensing section (Koach, 1998). Other papers will be published in the near future.

Introduction

The environment of Kuwait has been severely disrupted by the military operations and the oil well fires during the different phases of the Gulf war (1990 - 1991). Transportation of troops, ground fortification, mines plantations caused intensive environmental damages to soils, vegetation microrelief and other elements.

To assess the environmental impact of the main activities that took place before the invasion and during different phases of the Gulf War, the matrix system is applied. In this matrix, the main activities are tabulated against the environmental parameters. The latter include physical-chemical, ecological and aesthetic (Table 1).

To evaluate the environmental effects of the main activities, the Leopold matrix style (Munn, 1979) is applied with slight modification. Scoring from 10 to

only fresh water reservoir in the country. In addition, some military operations during the liberation phase affected the spreading of surface runoff. These activities include heavy air bombing and off-road transportation. This impact is rated moderate to severe depending on the magnitude of military operations.

- During the rehabilitation phase , extinguishing of oil fires using seawater affected the water quality and probably the level of sub-soil water (mainly in the northeastern and southwestern areas). This impact is rated moderate (Al-Besharah 1991, 1992 and Literathy 1992). Other activities during the rehabilitation may have certain effects on runoff spreading in the notheastern, western and southwestern areas. These activities include digging of demolition pits and landfills and refilling of trenches and bunkers.

Land Parameters. The land parameters sustain the highest damage through the different phases of the war (Fig. 7 and Table 5). These parameters considered in the impact assessment include soil erosion, sand movement, soil compaction, soil suitability for agricultural use, micro-relief and topographic characters, compatibility for land use and unique physical features. These parameters were influenced to different degrees by the various activities in the studied areas (Table 7 and fig. 9) Intensive field survey and satellite images were used to estimate the environmental damage inflicted on the land parameters (Al-Ajmi et al. 1994). In addition, military reports (Ministry of Defence 1993 and Friedman 1991) and several studies, conducted before and after the war were considered, such as, Al-Houty et. al. (1993), Abdal and Al-Ajmi (1992), Al-Awadi et. al. (1992), Khalaf (1990), Khalaf and Al-Ajmi (1993), Khalaf et al. (1994), Zaman and Al-Sdirawi (1993), UNEP (1991), Omar (1985), McGill et al. (1981), Khalaf et al. (1980), Khalaf et al (1982), Khalaf (1988, 1989), Foda et al. (1984) and Foda et al. (1985).

Soil erosion and sand movement were stimulated by the military operations during occupation, liberation and rehabilitation. The ground entrenchment and refilling, the off-road vehicles, and the ordnance and explosive disposal activities were the most significant of these operations. Locally, in the oil fields in the northeastern and southwestern ereas, the loose fragile soils were temporarily stabilized by oil spills and oil mist. In addition, wind erosion was locally controlled

in the areas of strategic mine fields during the occupation, liberation and early stages of the rehabilitation. Later on, these areas were subjected to severe degradation through mine clearance and detection. At least 15 cm of the topsoil of the mentioned areas was disturbed through mechanical mine removal.

Off-road traffic during occupation, liberation and rehabilitation was the main cause of soil compaction. This will result in a remarkable decrease of soil recharge by precipitated water. In addition, the ratio of runoff water may increase, causing water erosion.

Soil suitability for agricultural use, micro-relief and topographic characters, compatibility for land uses and unique physical features were influenced by the military operations and oil well fires. The degree of influence varies in different areas.

Atmosphere. Two atmospheric parameters are considered: air quality and temperature. The effect of different activities during the different phases of the war on these parameters was relatively low. The PTEIGE ranges from 2% in the western area to 5% in the southwestern area (Fig. 7 and Table 5). Activities affecting air quality and temperature involved oil well fires (January-November 1991), air raids and the ground campaign (January 17-February 26, 1991) and demolition of unexploded ordnance during the rehabilitation phase.

Fig. 10 and Table 8 show that the impact of the total activity on air quality is much higher than the impact on temperature. The massive amount of smoke emitted during the ten months oil fires had formed a large cloud that prevented the sun radiation from reaching the ground; this caused a significant drop in the air temperature during that period. Abdali (1993) mentioned that an increase in the minimum temperature was detected for the year 1991 - 1992 compared with the previous years. Meanwhile, a decrease of the maximum temperature in the same period was observed. Abdali (1993) stated that, during the time of oil fires, the generated soot and plume were reflecting and absorbing a large amount of incoming short-wave radiation during daytime, which led to cooling effects of 10C immedaitely under the plume. At night, the terrestrial long wave radiation and the counter-radiation generated from the plume increased the minimum temprature.

However, this effect lasted for a relatively short period of time and did not cause any significant environmental impact. On the other hand, oil well fires in

the northeastern and southwestern areas had a servere effect on air quality. Infallible soot extending downwind of oil field represents a main source of vanadium. In addition, oil lakes emit volatile organic components, which are of great risk to human health (Abdal and Al-Ajmi 1992, Abdali 1993 and Issa et. al. 1995). The effect of oil fires was moderate in the northeastern area and severe in the southwestern area during the rehabilitation phase.

Noise: The noise intensity, duration and repetition in the studied areas were rated servere during the liberation phase. In the rehabilitation phase, the effect was moderate to slight. The PTEIEs of the three noise components are of similar magnitude in all four areas (Table 8 and Fig. 11).

Ecological Characteristics. Ecological characteristics include biota (vegetation and wildlife). In addition to the field survey and the analyses of satellite images (Al-Ajmi et al. 1994), several scientific papers evaluated the degree of damage to environmental parameter (Al-Houti et al. 1993; Al-Rawi 1987; Boulos 1988; Daoud 1985; Dibble and Bartha 1979; Dickson and Macksad 1973; Halwagy and Halwagy 1974; Karrar et al. 1991; Macksad 1969; Murris 1980; Omar 1985; Owen and Nasr (1958). Fig. 12 and Tables 5 and 8 show the degree of effects on biota relative to other environmental parameters. It can be seen that the effects are relatively severe and of similar magnitude in all four areas. The following describes the effects on the two mentioned parameters of the ecological characteristic:

Vegetation. Activities during the occupation phase (ground digging, mine implantation, building of new desert road, establishing of sandy barriers and off-road traffic) had significant impact on vegetation density. This effect was rated moderate in the northwastern and western areas to severe in the northwestern and southwestern areas.

Activities during the liberation phase (air raids, ground campaign and oil well fires) had a remarkable impact on vegetation density. This effect was rated extremely severe in the northeastern, western and southwestern areas to severe in the northwestern area.

During the rehabilitation phase, the oil well fires control and the explosives and ordnance disposal operations had significant effects on the vegetation cover.

This effect was rated moderate in the northeastern, northwestern and western areas to severe in the southwestern area.

Wildlife. Birds, reptiles and insects were influenced to different degrees during the various phases of the Gulf war. During occupation, the military operations affected the wildlife. The effect was rated moderate. During liberation, (air raids, land battles and oil fires) had severe effects on wildlife. During rehabilitation, refilling of trenches and bunkers, demolition activities, oil well fires control and off-road vehicles had moderate effect on wildlife.

Generally, the various activities that took place in the different phases of the Gulf war had variable effects on wildlife. The impact on birds ranges between 17 and 20% of the total effects on biota, wherease that on reptiles averages 22% of the total effect on biota. On the other hand, the effect on insects represents 13-16% of the total effects on biota.

Aesthetic Characteristics. The following aesthetic parameters are considered in the environmental impact asseeement: land (relief and topographic characteristics), atmosphere (odor, visual and sounds), water bodies (appearance, odor and taste) and biota (animals and diversity of vegetation). These parameters were influenced to different degrees by the various activities that took place in the studied areas (Fig. 13 and table 9).

Land. Pre-invasion activities did not affect the aesthetic nature of relief and topographic characteristics, except in northwestern area, where quarrying and related operations had a servere effect.

During occupation, the defence facilities (trenches, bunkers, weapon pits, oil trenches, sand barriers, obstacles, barbed wire) and war machinery influenced the aesthetic scenes of relife and topographic characteristics. This effect was rated severe in the northeastern area, moderate in the western and southwestern area and slight in the northwestern erea.

During liberation, air raids, ground campaigns and oil well fires (spilled oil, oil mist and soot) had different effects on the aesthetic nature of relief and topographic features. In the northeastern and northwestern areas, these activities had moderate impact, whereas in the southwestern and northwestern areas, the impact was severe and slight, respectively.

In the rehabilitation phase, oil fires extinguishing had moderate to slight effect on the aesthetic scene of relief and topographic features.

Atmosphere. Pre-invasion activities had no significant impact on the atmosphere, except in the northwestern area, where quarrying had severe visual effect.

During liberation, air raids, land battles, and oil fires had different effects on the atmosphere. These activities had servere to moderate effects on the odor, visual and noise in the northeastern and southwestern areas. In the northwestern area, air raids and the ground campaign had moderate to servere effect on odor, sound and visual characteristics. In the western area, these activities had moderate effect on odor, visual and noise. During liberation, demolition of unexploded ordnance had moderate to severe effect on sound levels. On the other hand, oil fires affected the temperature. This effect was considered moderate.

Military operations (mainly air raids and the ground campaign) affected air quality. The effect was rated moderate in the northeastern, northwestern, and southwestern areas, and servere in the western area.

Noise: Three noise-related parameters are considered. These are noise intensity, duration and repetition (Fig. 11 and Table 8).

Noise effects resulted mainly during air raids and the ground campaign (liberation phase), and demolition of unexploded ordnance in scattered spots.

Water Bodies. In the northeastern area, barbed wire, armored lines, minefields, etc significantly affected the water of Kuwait Bay and Khor As-Subiyah.

These obstacles affected the aesthetic appearance of the shoreline.

Biota. During the occupation phase, the presence of barbed wire and armored lines in the intertidal zone of the northeastern area disturbed the habitat of animals.

Fish were also killed, affecting the beauty of the shoreline, especially the mudflats with their jumping mudskippers.

During liberation, oil spills, oil mist and soot in the northeastern and southwestern areas affected the animals and plants, leading to a negative impact on the natural beauty. This effect was rated moderate in the northeastern area and server in the southwestern area.

Conclusions

Based on the results of the environmental impact assessment, the following are concluded:

1. The liberation phase activities inflicted the most adverse environmental impact on the environment; whereas the activities during the pre-invasion phase had the lowest environmental impact.
2. Oil fires and their consequences had the greatest impact on the environmental elements.
3. Land parameters were highly affected by the different activities followed by aesthetic and biota. The effect on the atmospheric parameters was relatively low. This was attributed to the fact that only oil fires had a major impact on the atmospheric parameters and this effect lasted for a relatively short period of time.

The southwestern area is the most severly damaged area. The main cause of damage was the oil well fires and their consequences and military operations. The northeastern area, which contains vital water resources, followed in the rate of damage. Both military operations and oil well fires and consequences damaged this area. The western and northwestern areas affected by military operations follow in the degree of damage.

Acknowledgements

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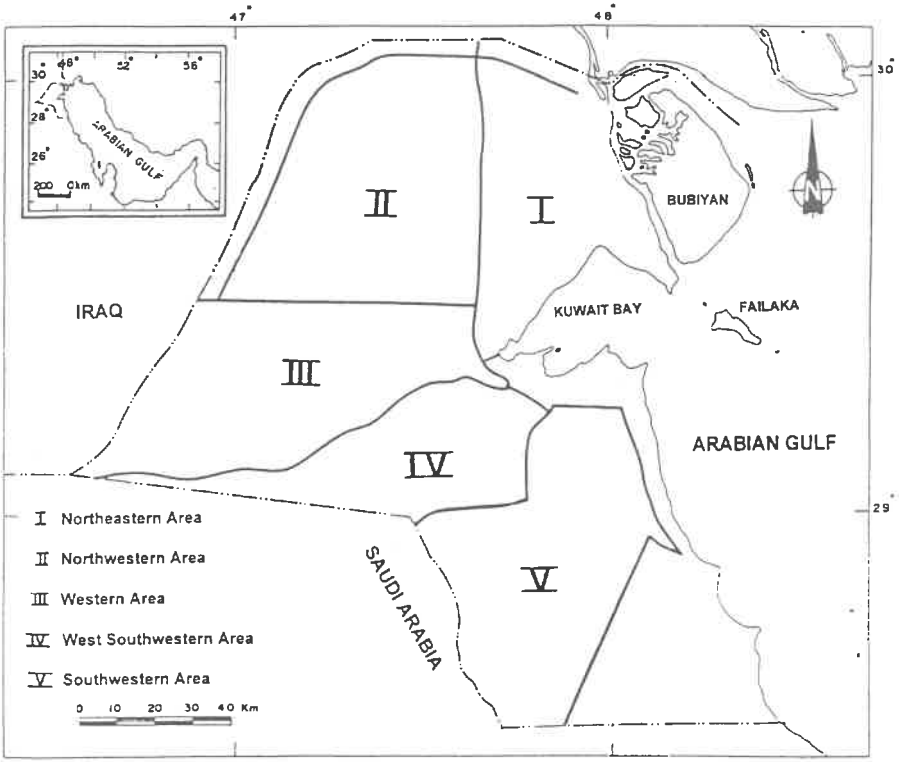

Figure. 1: Locations of the areas selected for damage assessment

Table (1) The Matrix System

Areas of Potential Environmental Impact			Environmental Parameters \ Activities	I					II								III							IV				
				1	2	3	4	5	a	b	c	d	e	f	g	h	i	A	B	C	D	E	F	i	ii	iii	iv	v	vi
Physical - Chemical	Water	Ground Water	Water Level																										
			Water Quality																										
		Surface Runoff	Water Quality																										
		Sea Water	Pattern of Distribution																										
	Land		Soil erosion																										
			Sand movement																										
			Soil compaction																										
			Soil suitability for agricultural use																										
			Microrelief & topographic character																										
			Compatiblity for land uses																										
			Unique physical features																										
	Atmos-phere		Air quality																										
			Temperature																										
	Noise		Intensity																										
			Duration																										
			Repetition																										
Ecological	Biota	Vege-tation	Density																										
			Diversity																										
		Wild Life	Birds																										
			Insects																										
Aesthetic		Land	Relief and Topographic Character																										
			Physical Infrastructure																										
		Atmos-phere	Odour																										
			Visual																										
			Sounds																										
		Water Bodie	Appearance																										
			Odour, Taste																										
		Biota	Animals																										
			Diversity of Vegetation																										

Description of the activities:

I: Before Invasion

1) Quarrying & Related off-Road Traffic. 2) Military Installations & Related Activities. 3) Oil Installations & Related Activities. 4) Recreation Camps. 5) Grazing & Related Activities.

II: Occupation

a) Off-Road Traffic. b) Sand Barriers (Bundwalls). c) Barbed Wires. d) Mine Implantation. e) Bunkers. f) Trenches. g) Oil in Trenches. h) Military Equipment (Machinery, Tanks, Vessels). I) Military Forces.

III: Liberation

A) Air Raids. B) Land Battle. C) Soot Cover. D) Oil Fires. E) Oil Mist Precipitate (Tar Crust). F) Oil Lakes (Tar Mats).

IV: Rehabilitation

i) Oil Fire Extinguishing. ii) Obstacle Removal (Barbed Wire, etc.). iii) Manual Mine Removal. iv) Mechanical Mine Removal. v) Automobile and Pedestrian Movement. vi) Dredging and Filling. vii) Wreck. viii) Demolition of Unexploded Ordnance.

Table (2) Percentage of Main Activities During Pre-invasion and Occupation Phases.

Phase	Pre - invasion					Occupation								
Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Area														
NE	1	19	41	16	23	18	16	8	1	20	19	0	14	4
NW	90	0	0	0	10	39	22	0	0	19	0	0	16	4
W	34	28	0	8	30	13	12	4	11	15	0	23	16	5
SW	0	18	73	0	10	10	13	5	3	12	17	25	10	5

1: Quarrying & Related Off-Road Traffic
2: Military Installations & Related Activities
3: Oil Installations & Related Activities
4: Recreation Camps
5: Grazing & Related Activities
6: Off-Road Traffic
7: Sand Barriers (Bundwalls)
8: Barbed Wire
9: Mine Implantation
10: Bunkers
11: Trenches
12: Oil Trenches
13: Military Equipment (Machinery, Tanks, Vessels)
14: Military Force

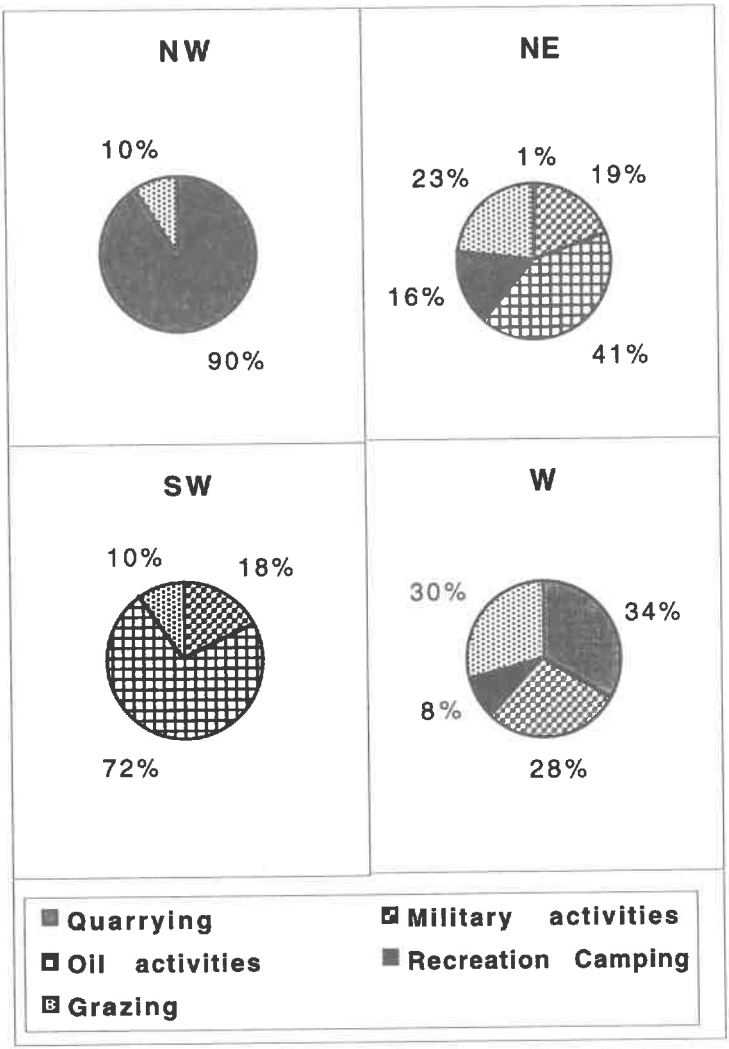

Figure 2: Precentages of the total impact main activities on the environmental elements in the pre-invasion phase.

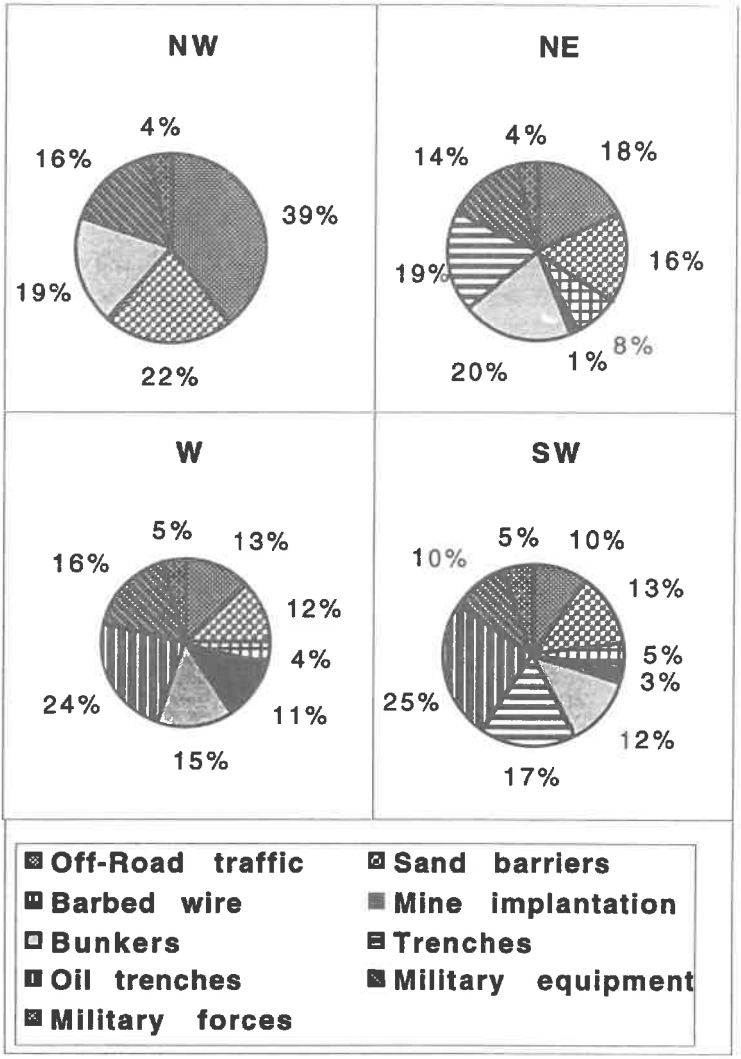

Figure 3: Precentages of the total impact of main activities on the environmental elements during the occupation phase.

Table (3) Precentages of Main Activities During Liberation and Rehabilitation Phases.

Phase	Liberation					Rehabilitation								
Activity	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Area														
NE	16	27	9	20	14	14	26	12	2	6	8	20	5	20
NW	38	62	0	0	0	0	0	0	2	0	27	33	10	28
W	28	72	0	0	0	0	0	11	5	25	15	19	5	19
SW	15	30	10	13	13	13	26	12	1	12	14	17	5	13

15: Air Raids

16: Land Battle

17: Soot Cover

18: Oil Fires

19: Oil Mist Precipitate (Tar Crust)

20: Oil Lakes (Tar Mats)

21: Oil Fire Extinguishing

22: Obstacle Removal (Barbed Wire, etc.)

23: Manual Mine Removal

24: Mechanical Mine Removal

25: Automobile and Pedestrian Movement

26: Dredging and Filling

27: Wreck

28: Demolition of Unexploded Ordnance

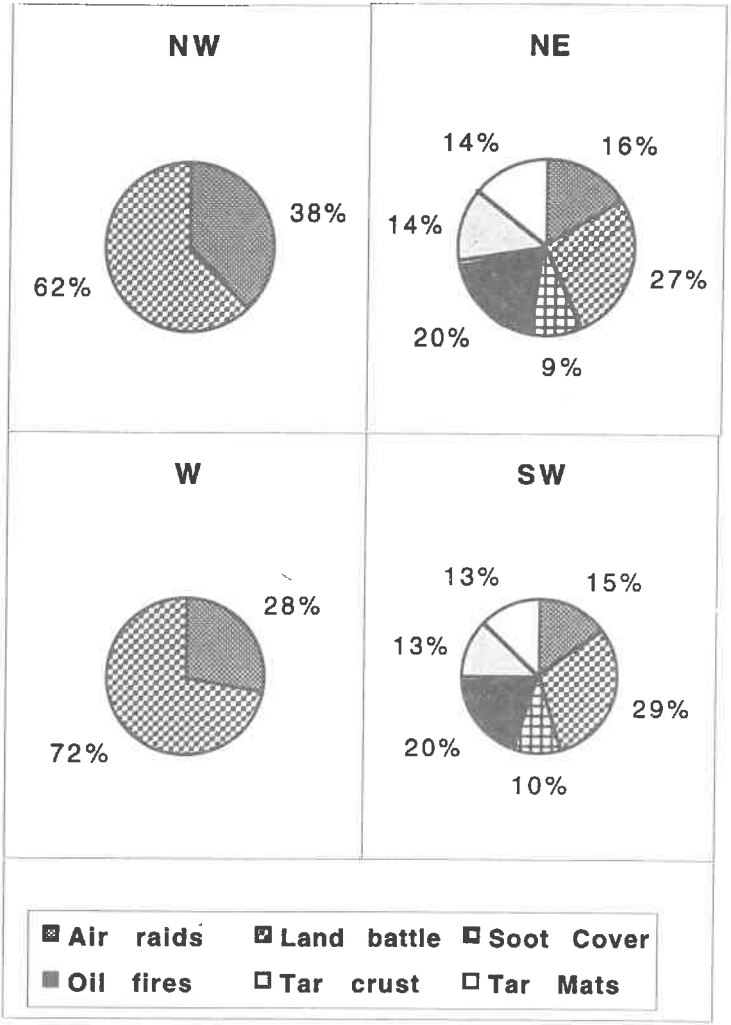

Figure 4. Percentages of the total impact of main activities on the environmental elements during the liberation phase.

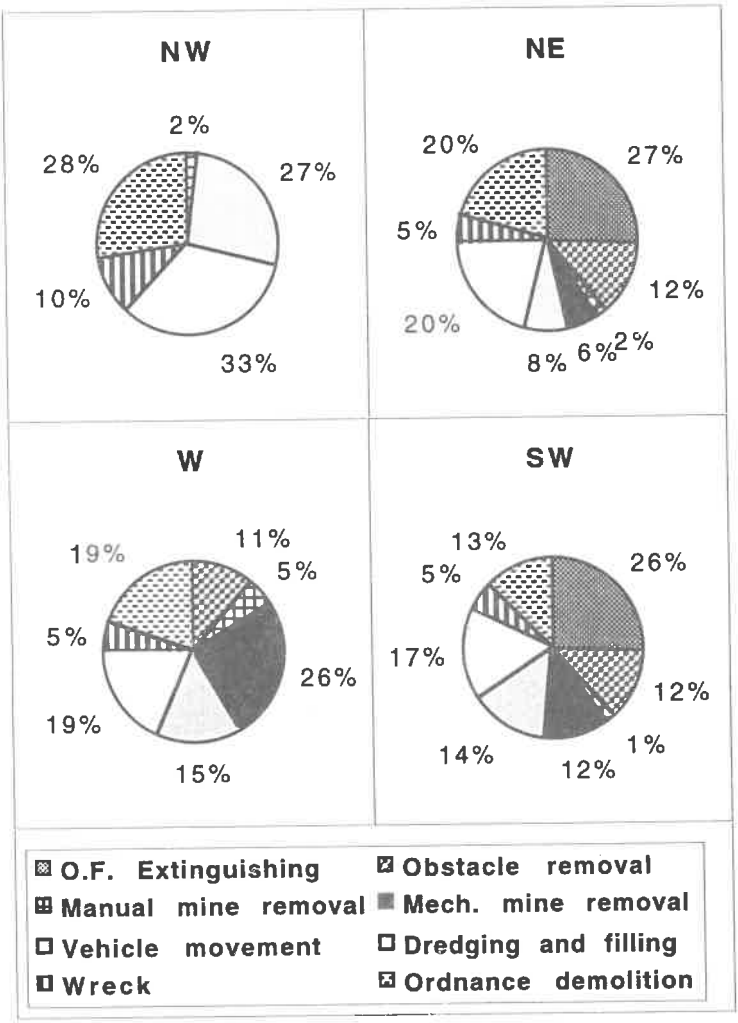

Figure 5.: Percentages of the impact of main activities on the environmental elements during the rehabilitation phase.

Table (4) Percentages of the total impact of main activities on the environmental elements Before Invasion and During Different Phases of the Gulf War.

Phase	Pre-invastion	Occupation	Liberation	Rehabilitation
Area				
NE	10	23	39	28
NW	19	22	44	15
W	17	29	25	29
SW	6	17	44	32

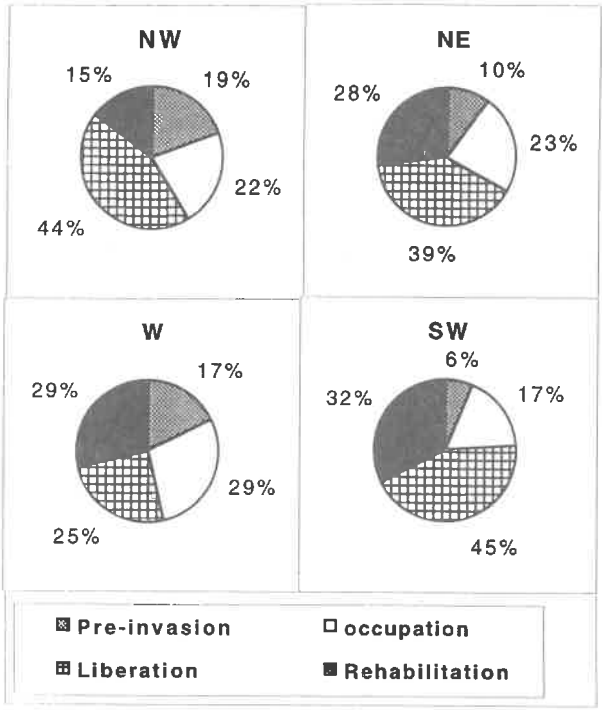

Figure 6: Percentages of the total impact of main activities during the different phases.

Table (5) Percentages of Different Effects on Physical-Chemical, Ecological and Aesthetic Parameters

	Elements of Potential Impact					
	Physical - Chemical				Ecological	Aesthetic
	Water	Land	Atmosphere	Noise	Biota	
Area						
NE	10	30	4	7	21	27
NW	6	33	4	12	24	21
W	9	37	2	10	23	19
SW	9	31	5	8	22	25

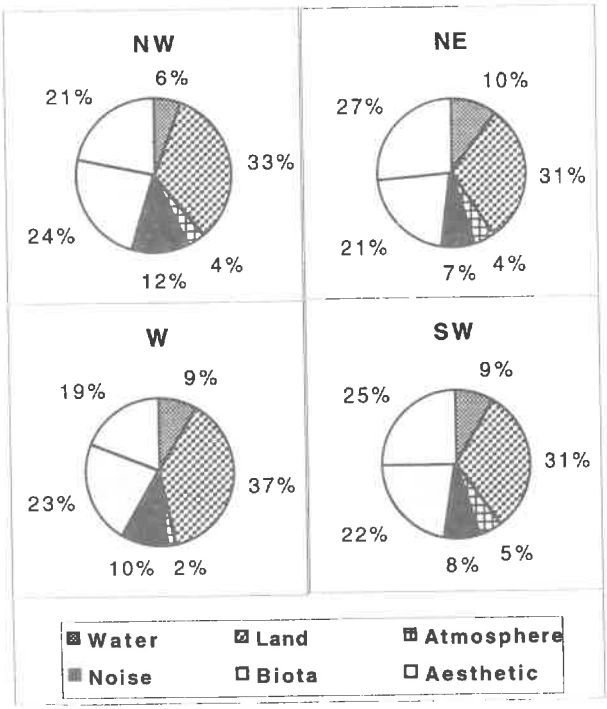

Figure 7. Percentages of the total impact of main activities on main environmental parameters.

Table (6) Percentages of Different Effects on Water

Area	Ground Water Level	Water Quality	Runoff Water Quality	Runoff Water Distribuation	Sea Water
NE	12	17	25	44	2
NW	0	1	3	96	0
W	4	6	16	74	0
SW	8	16	28	48	0

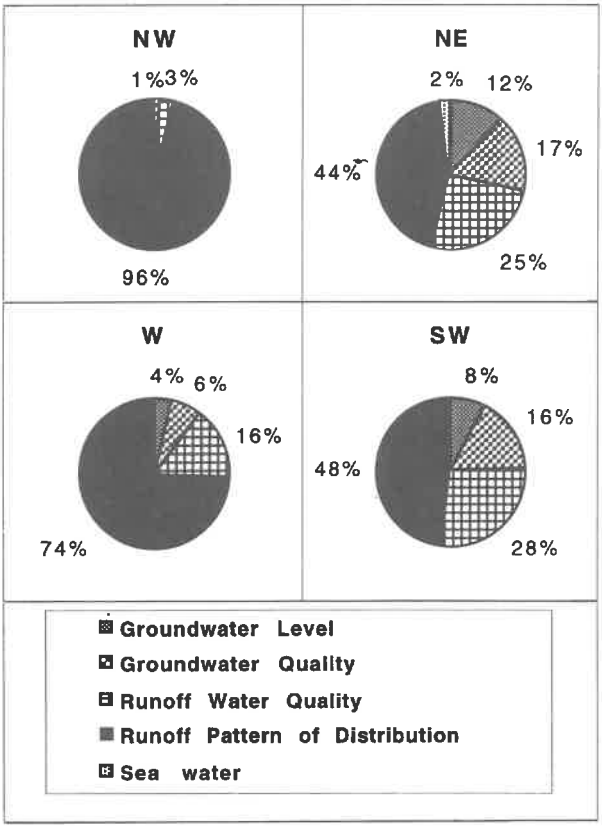

Figure 8. Percentages of the total impact of main activities water parameters.

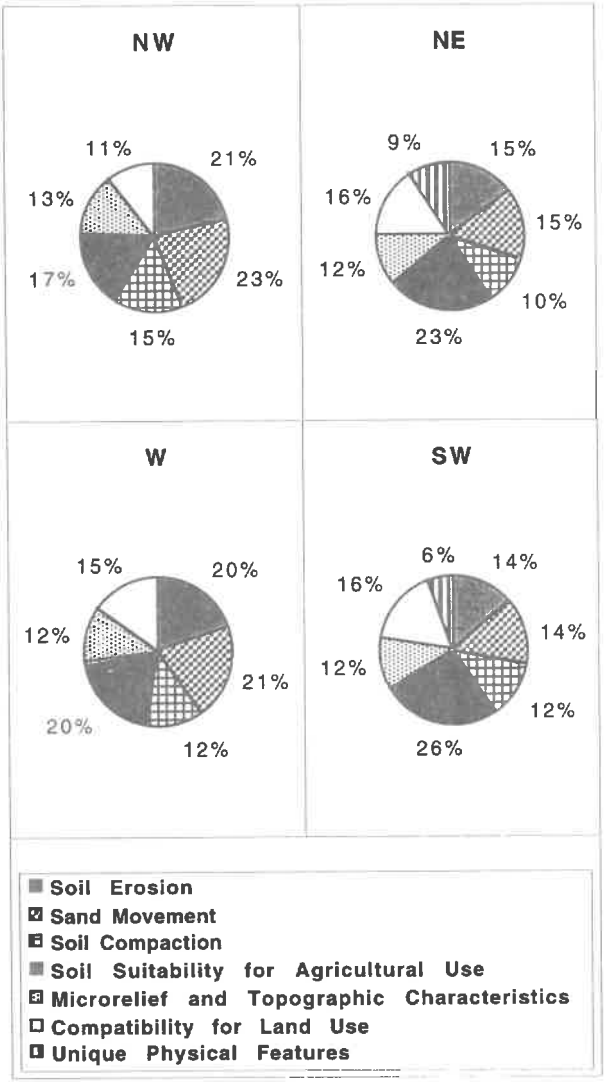

Figure 9. Percentages of the total impact of main activities land parameters.

Table 7. Percentages of Different Effects on Land.

	A	B	C	D	E	F	G
Area							
NE	15	15	10	23	12	16	9
NW	21	23	15	17	13	11	0
W	20	21	12	20	12	15	0
SW	14	14	12	26	12	16	6

A: Soil Erosion

B: Sand Movement

C: Soil Compaction

D: Soil Suitability for Agricultural Use

E: Microrelief and Topographic Characteristics

F: Compatibility for Land Use

G: Unique Physical Features

Table (8) Percentages of Different Effects on Atmosphere, Noise and Biota.

	Atmosphere		Noise			Biota				
						Vegetation		Wild Life		
	Air Quality	Tem.	Intensity	Duration	Repetition	Density	Diversity	Birds	Reptiles	Insects
Area										
NE	86	14	33	31	36	39	9	19	22	10
NW	99	1	40	33	27	37	11	18	22	12
W	98	2	42	31	27	46	13	14	21	7
SW	87	13	39	33	28	36	9	19	22	14

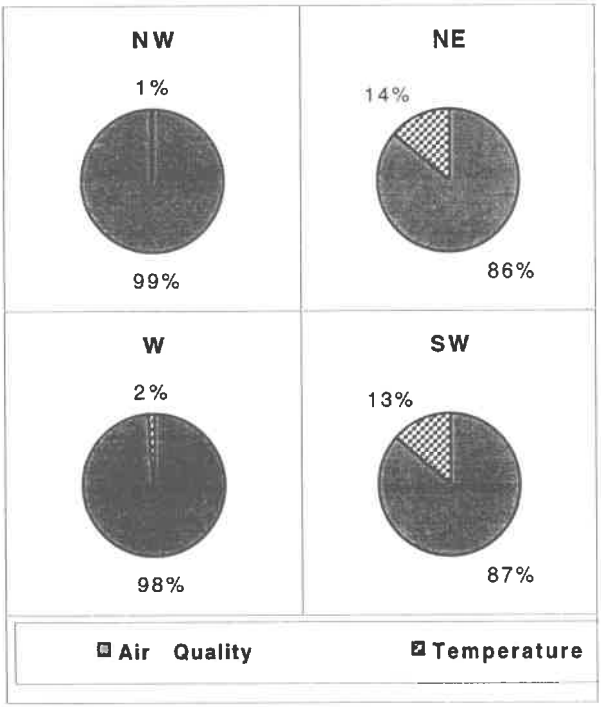

Figure 10. Percentages of the total impact of main activities, atmospheric parameters.

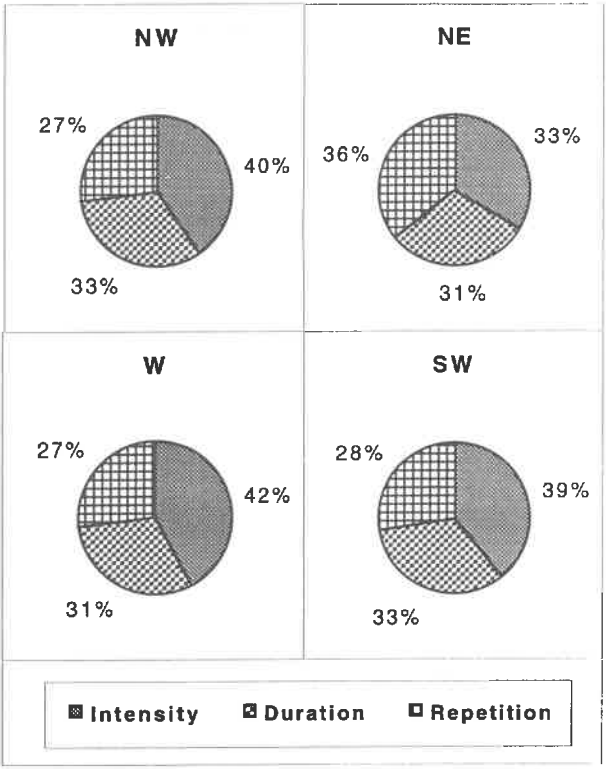

Figure 11. Percentages of the total impact of main activities, noise parameters.

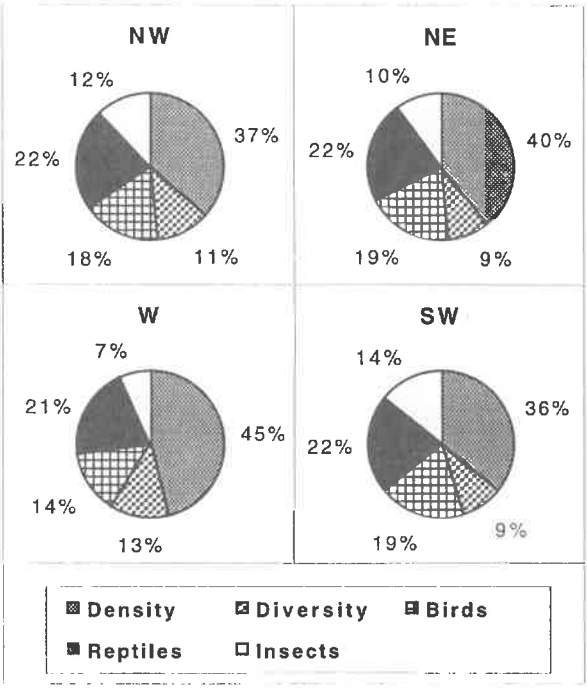

Figure 12. Percentages of the total impact of main activities, biota parameters.

Table (9) Percentages of Different Effects on Aesthetics.

	Land		Atmosphere			Water Bodies		Biota	
	Relief	Infrastructures	Odor	Visual	Sounds	Appearance	Odor & Taste	Animals	Vegetation Diversity
Area									
NE	20	11	11	13	10	8	5	15	6
NW	20	5	13	20	20	0	0	14	8
W	25	0	11	17	20	0	0	15	12
SW	22	15	14	14	2	0	0	17	7

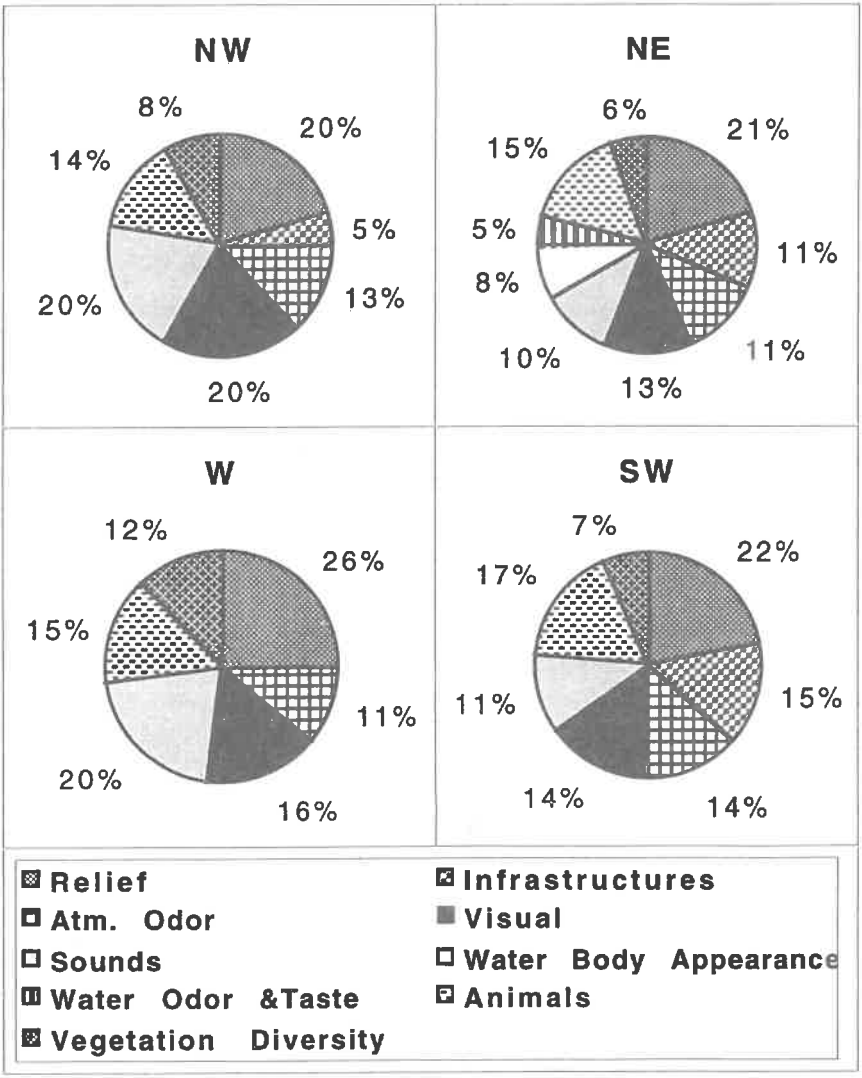

Figure 13. Percentages of the total impact of main activities on aesthetic parameters.

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المجلة العربية للمحاسبة

مجلة علمية متخصصة ومحكمة نصف سنوية تصدرها اللجنة الدائمة لأقسام المحاسبة بجامعات دول المجلس - جامعة البحرين - دولة البحرين

أهداف المجلة

١ - المساهمة في تنمية الفكر المحاسبي وتطبيقاته من خلال نشر البحوث النظرية والتطبيقية في المحاسبة بمجالاتها المختلفة .

٢ - إتاحة الفرصة للمفكرين والباحثين في المحاسبة بنشر نتاج أنشطتهم العلمية والبحثية وخاصة تلك التي تتصل بالبيئة والمجتمع العربي بصفة عامة ودول الخليج بصفة خاصة .

٣ - متابعة المستجدات في الأنشطة المحاسبية العلمية والبحثية والتعليمية والمهنية من خلال عرض مراجعات الكتب الجديدة والمؤتمرات والندوات العلمية وملخصات الرسائل الجامعية والتعليقات العلمية . والحالات العلمية ذات القيمة في التطبيق العملي في البيئة العربية .

٤ - إقامة والمشاركة في الندوات والمؤتمرات العلمية ذات الصلة بمجالات اهتمام المجلة.

دعوة للمساهمة

يسر المجلة العربية للمحاسبة دعوتكم للمساهمة في أحد أبوابها التالية :

- الأبحاث العلمية في كافة فروع المحاسبة والمجالات المعرفية ذات الصلة ، والمكتوبة باللغة العربية أو الإنجليزية.
- مراجعات الكتب العربية والأجنبية من الإصدارات الحديثة والتي تهم الباحثين والممارسين في مختلف المجالات المحاسبية في الوطن العربي .
- التقارير عن الندوات والمؤتمرات وحلقات النقاش العربية التي تهم الباحثين والممارسين في مختلف فروع المحاسبة.

المراسلات

توجه المراسلات على العنوان التالي :

المجلة العربية للمحاسبة
جامعة البحرين - قسم المحاسبة
كلية إدارة الأعمال
ص . ب : ٣٢٠١٠
دولة البحرين
- تليفون : ٤٤٩٠٩٧ (٩٧٣)
- فاكس : ٤٤٩٠٩٦ (٩٧٣)

الاشتراكات السنوية

للأفراد	سنة	سنتان	ثلاث سنوات
دول مجلس التعاون	٢ دينار بحريني	٤ دينار بحريني	٦ دينار بحريني
الدول العربية	٣ دينار بحريني	٥ دينار بحريني	٧ دينار بحريني
البلاد الاخرى	١٠ دولاراً امريكياً	٢٥ دولاراً امريكياً	٣٥ دولاراً امريكياً

للمؤسسات			
دول مجلس التعاون والدول العربية	١٥ ديناراً بحرينياً	٢٥ ديناراً بحرينياً	٤٠ ديناراً بحرينياً
البلاد الأخرى	٦٠ دولاراً امريكياً	١١٠ دولاراً امريكياً	١٥٠ دولاراً امريكياً