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BIOSTIMULATION METHOD IN SHORELINE CLEAN-UP – AN APPROACH OF COASTAL ENVIRONMENT MANAGEMENT IN RESPONSE TO OIL-SPILL HAZARD – CASE STUDY GANH RAI GULF- VIET NAM

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Abstract

According to geographical and economic features, the coastal area surrounding of the Ganh Rai gulf, in south of Viet Nam, is extremely sensitive to oil-spill hazard. Most of the area is covered by mangrove forest; therefore an effective means for shoreline clean – up and a sacrificial area are the hard tasks in contingency plan for oil spill response.

The paper presents the result of the application of the biostimulation method on spilled oil contaminated materials of the area. Diesel oil (DO) and fuel oil (FO) were experimented in the case study. The result proves that the biostimulation method can be applied effectively for the shoreline clean-up and it brings to the ability of defining the sacrificial zones in the contingency plan in response to oil spill hazards of the area.

Key words: biostimulation, shoreline, oil spill, diesel oil, fuel oil.

1. Introduction

According to the environmental sensitivity categories for the shoreline from Mui Ne to Tien River in response to oilspill hazard (Hang&Vinh- 2002); Ganh Rai gulf is placed in the extremely sensitivity by the natural and man – made factors as follows:

With natural factors:

- Well sheltered shoreline
- The coast type is tidal flat of the river mouth formed by fined materials on which mangrove forest is widespread.
- The natural resources are vital and diverse.

With man-made factors:

- The concentration of petroleum activities are dynamic and crowded both onshore and offshore.
- The activity of many commercial seaport and fluvial port (Sai Gon, Dong Nai, and Thi Vai-Cai Mep, etc.) are in a rush.
- The diversity of economic activities that run over whole year (Table 1).

As the entrance of the important waterway to the important fluvial ports of main-point economic zone of South Viet Nam, Ganh Rai gulf is faced with the risk of the increasing of oil spill hazard (Table 1).

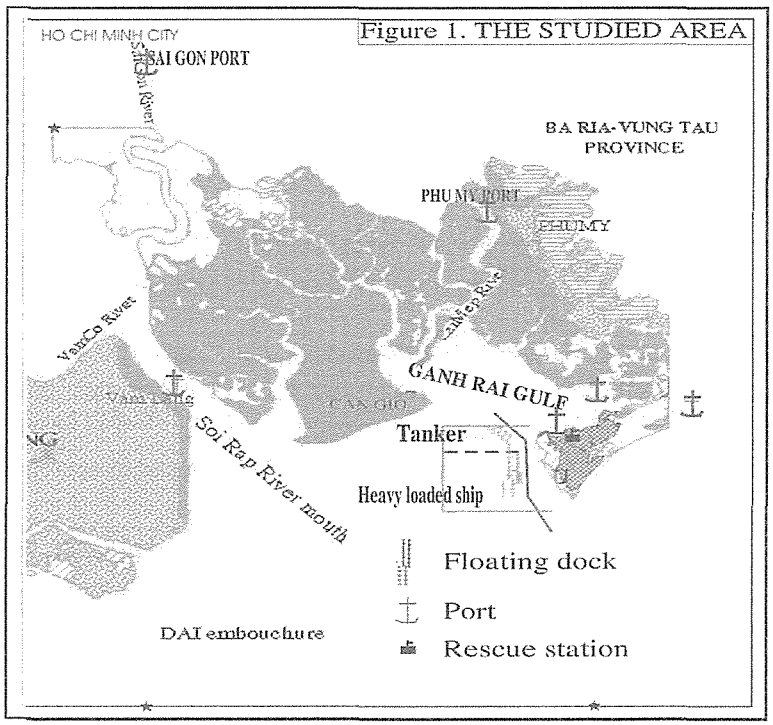
Table 1- The oil-spill hazards happened in Ganh Rai Gulf and its surrounding from 1993 -2003 [2]

Time	Cause	Position	Spilled oil (tons)	Oil type	Economic Lost
18/09/ 1993	Pan Haverst ship sank	Ky Van Cape	300	FO, DO	unknown

08/05/ 1994	Humanity ship(Taiwan) and Transco-01ship(VN) collided	Long Tau river	130	FO	11 billion VND
03/10/ 1994	The collision of Neptune Aries ship (Singapore)	Cat Lai Port on Dong Nai river	1700	DO	36 billion VND
27/01/ 1996	The collision of Gemini ship (Singapore)	Cat Lai Port on Dong Nai river	72	Raw oil, Condensate	4 billion VND
16/08/ 1998	Sokimex 12 ship (VN) hit against barge	Nha Be river	41	DO	3 billion VND
16/04/ 1999	Hiep Hoa 2 ship hit against Nhat Thuan ship	Nha Be river	97	DO	1.8 billion VND
07/09/ 2001	Formosa One ship hit against Petrolimex 01 ship	Dock of Ganh Rai gulf	900	DO	260 billion VND
12/01/ 2003	The collision of Barge and Fortune ship	Sai Gon Port	500	DO	Unknown, Severe pollution
20/03/ 2003	Hoang Anh ship sank	Bouy No. 7 in Ganh Rai gulf	100	FO, DO	Unknown
26/08/ 2003	Ha Loc 02 ship hit against Viet Thang ship	Ganh Rai gulf	100	DO	Unknown

The table 1 shows that 90% accidents belong to the medium to large scale, 10% is very large scale of ship.

The spilled oils can not be cleaned up completely, especially from the fine material of estuarine area; they are kept in the soil for long time and cause long term damage not only for economical situation but also for the ecosystem of the mangrove forest. Among the effort to minimize the lost from the oil-spill hazards, biostumilation is a new approach for the area.



2. Biostimulation application

Biostimulation method were applied to investigate the rate of DO and FO degradation by adding nutrients (nitrogen (N) and phosphorous (P)) in the oil - polluted sediment materials.

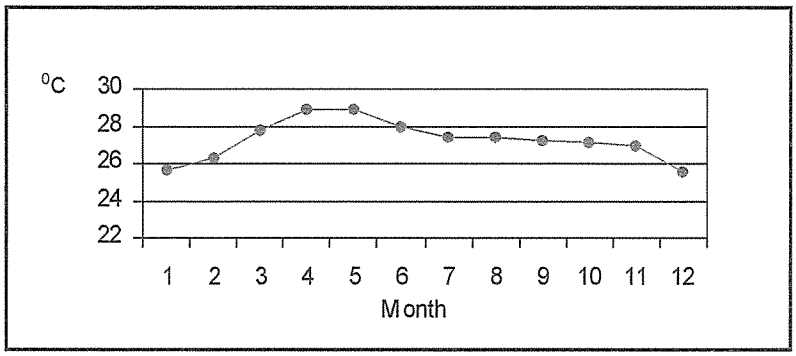
2.1. Principle of the method

Bioremediation is typically used as a polishing step, after using conventional cleanup methods. Biostimulation, in which nutrients, or other growth limiting substances, are added to stimulate the growth of indigenous oil degraders [4].

According to the environmental condition, the quantity and the species of microorganism change from place to place; commonly they expand largely in the soil rich of organic matters. Another factors affecting on the oil-biodegradation procedure are pH, salinity, radiation and ambient temperature. All of these factors are investigated in the experience.

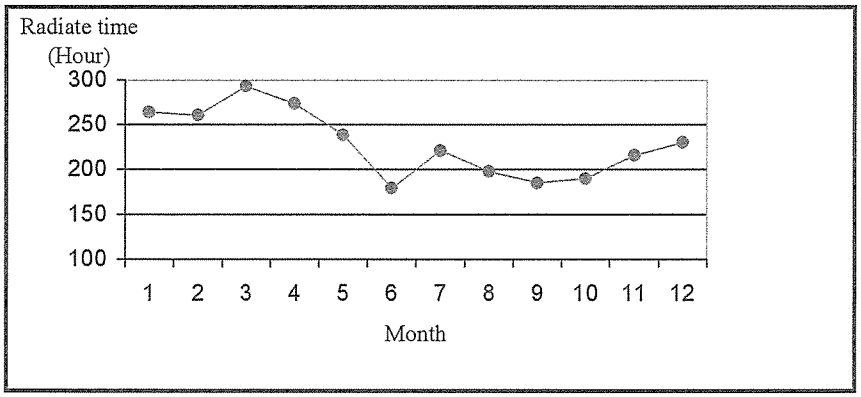
The figure 2 shows that the ambient air temperature is favorite for the growing of microorganism in whole year.

Figure 2. The average temperature of the studied area in 2000 [2]



The radiation of the area is rather high of which the favorite condition for the growing of microorganism is 10 – 20 cm under the ground.

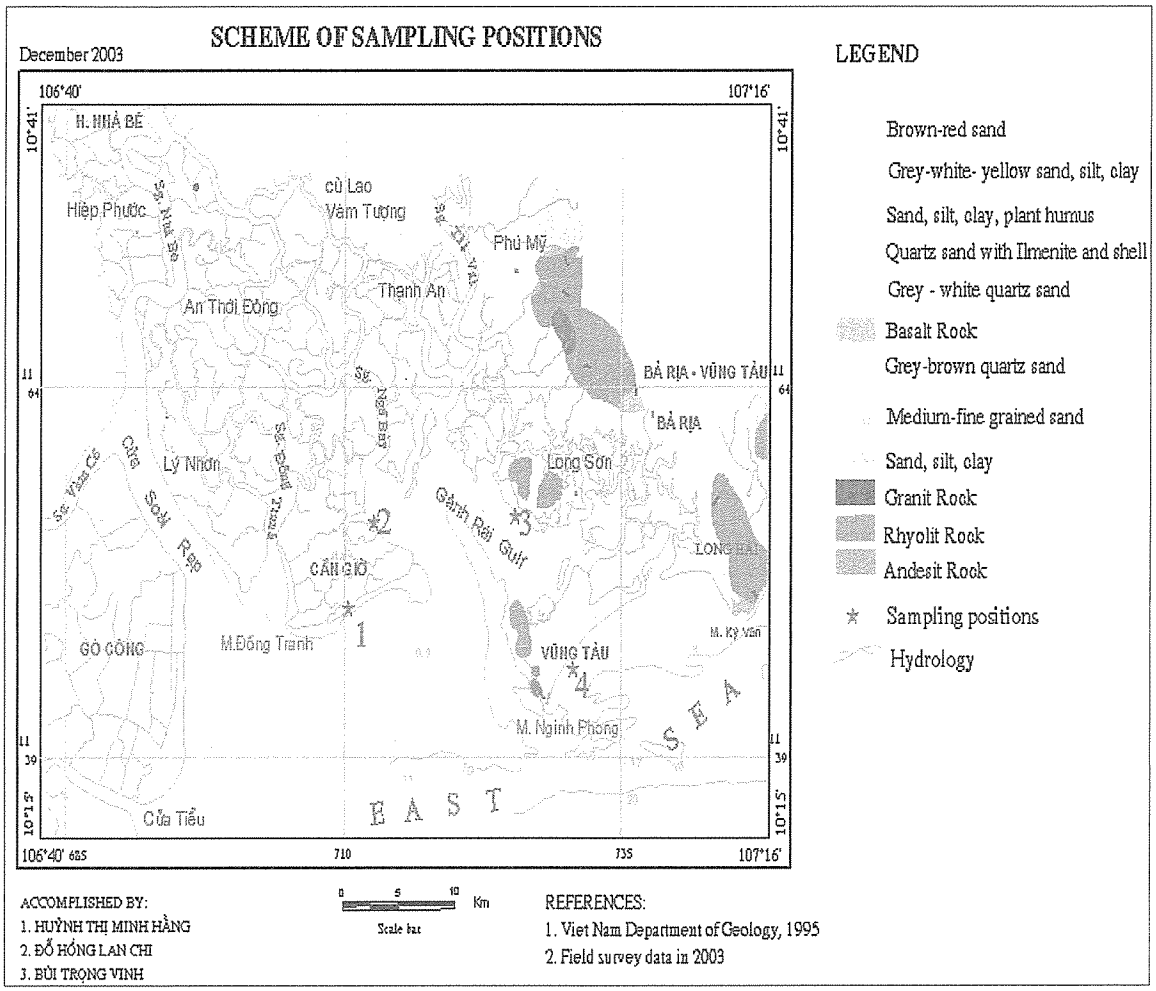
Figure 3. Total radiate time in average of the year 2000 [2]



2.2. Sampling and shoreline materials

The samples were taken in intertidal zone where the shore is affected by the irregular semi-diurnal regimes frequently. In due to the characteristics of coastal environments, four sampling positions were selected as presenting on the figure 4.

Figure 4. Scheme of sampling positions



Note: (1): Can Gio 1; (2): Can Gio 2; (3): Long Son; (4): Vung Tau

According to the particle of size the shoreline materials are placed from medium – grained sand to fine – grained materials such as mud and silt. Their distribution can be summarized as followings

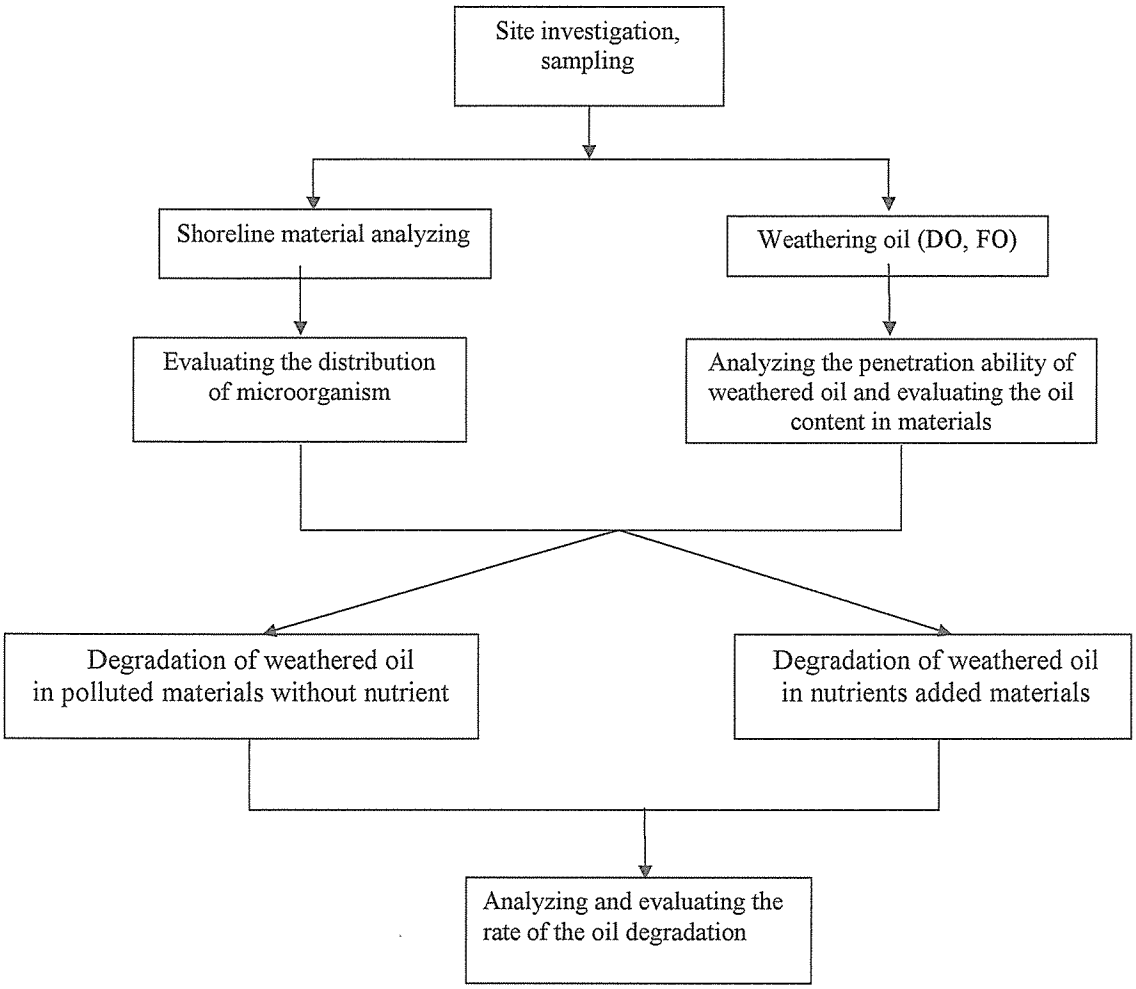
- The shore of Vung Tau are predominantly formed from medium - fine sand, but at some positions the material is rich of shell harsh, cobble, boulder and bedrock outcrop.
- The shore surrounding Ganh Rai gulf, including Can Gio, is formed predominantly from mud, silt and fine sand.

Table 2. Environmental feature at sampling time (October, 7th, 2003)

Position (on Fig. 4)	1	2	3	4
Sampling time	9AM	10 AM	3 PM	5PM
Temperature (^{0}C)	29.5	28	27.4	26.3
pH	8.15	7.97	8.09	8.46
Salinity (‰)	21	20	26.5	27.4

2.3. Experiment procedure

Figure 5. Experiment procedure



2.4. Experiment description

All experiments were carried out in the Laboratory of Institute for Environment & Resources (IER).

Experimentalised oils are DO and FO, the common spilled oils of the area. They were weathered artificially in the Laboratory in three days, the necessary times for the spilled oil penetrating in the sediment materials.

The analytical methods were used in the study:

- Microbiological analysis: Heterotrophic Plate count method was used to quantify the number of microorganism capable of growing on a Plate Count Agar (PCA) environment by counting the colonies formed.
- Analysis of nutrients: Total nitrogen and phosphorous were analyzed in response to the requirement of the Standard Methods (APHA,1995)
- Total Petroleum Hydrocarbon (TPH) analysis: It was measured on OCMA-350 by comparing the infrared absorption of the extraction liquid against that of a defined hydrocarbon mixture EPA 418.1 (U.S. EPA, 1992).

3. Results and discussion

3.1. The quantity of microorganism in sediment material

Table 3. The quantity of microorganism in the samples

Position of the sample (on the fig.4)	1 Can Gio 1	2 Can Gio 2	3 Longson	4 Vung Tau
Total bacterium (CFU/g)	175000	460000	200000	72500

CFU: colony forming unit

3.2. The rate of oil degradation

The result of biodegradation of weathered oil (DO and FO) in the sediment materials with nutrient (FOdd and DOdd) and without nutrient (FOkdd and DOkdd) are presented in the figures from No 6 to No 12.

The rate of biodegradation for DO and FO oil of the nutrient added materials are assessed in comparison with the natural materials (without nutrient adding)

Table 4. The variation of the content of DO related with the amount of microorganism, N and P in the sample No1

Time		1st Week Without nutrient	Nutrient adding		
			2nd week	3rd week	4th week
Nutrient	N (mg/l)	7	28.4	36.5	38.5
	P (mg/l)	0.6	4.3	5.6	4.6
Amount of microorganism (CFU/g)		175000	1750000	600000	576
DOdd (mg/kg)		211.2	127.6	80.8	72.9
DO kdd (mg/kg)		213.4	200.0	148.5	146.4

Table 5. The variation of the content of FO related with the amount of microorganism, N and P in the sample No1

Time		1st Week Without nutrient	Nutrient adding		
			2nd week	3rd week	4th week
Nutrient	N (mg/l)	7	40.6	46.4	48.4
	P (mg/l)	0.6	5.4	6.2	5.9
Amount of microorganism (CFU/g)		175000	60000	1000	405
DOdd (mg/kg)		230.1	153.0	130.5	108.9
DO kdd (mg/kg)		234.5	211.0	152.5	146.6

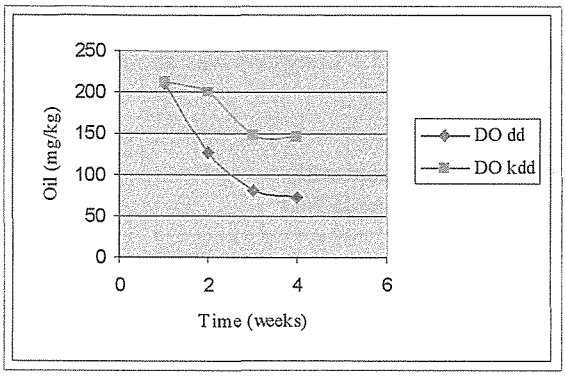


Fig.6. Biodegradation of DO in Can Gio 1

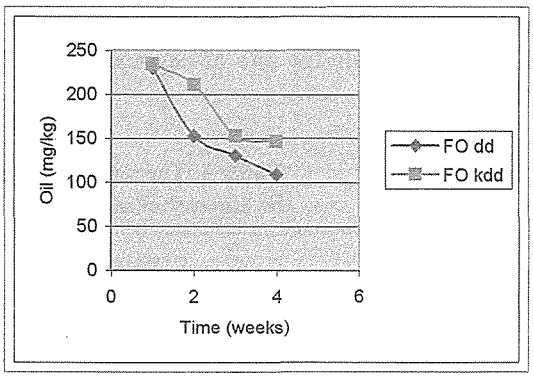


Fig.7. Biodegradation of FO in Can Gio 1

The rate of oil decreasing in the experiment sample No1 (Can Gio 1) is about 34.1% for DO and about 6.3% for FO

Table 6. The variation of the content of DO related with the amount of microorganism, N and P in the sample No2

Time		1st Week Without nutrient	Nutrient adding		
			2nd week	3rd week	4th week
Nutrient	N (mg/l)	8	18.6	24.6	28.6
	P (mg/l)	1.5	2.3	3.7	4.2
Amount of microorganism (CFU/g)		460.000	1.250.000	600.000	9.771
DOdd (mg/kg)		209.1	134	101	50.6
DO kdd (mg/kg)		215.2	152.6	137	126.2

Table 7. The variation of the content of FO related with the amount of microorganism, N and P in the sample No2

Time		1st Week Without nutrient	Nutrient adding		
			2nd week	3rd week	4th week
Nutrient	N (mg/l)	8	26.7	28.7	30.2
	P (mg/l)	1.5	2.9	3.8	4.6
Amount of microorganism (CFU/g)		460000	145000	9000	412
FOdd (mg/kg)		228.3	123.0	89.6	72.1
FO kdd (mg/kg)		231.4	210.0	187.2	156.2

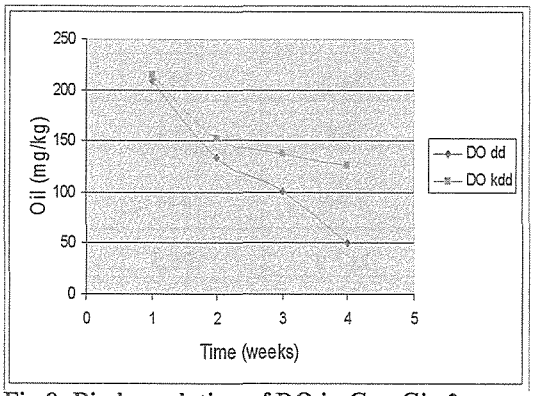


Fig.8. Biodegradation of DO in Can Gio 2

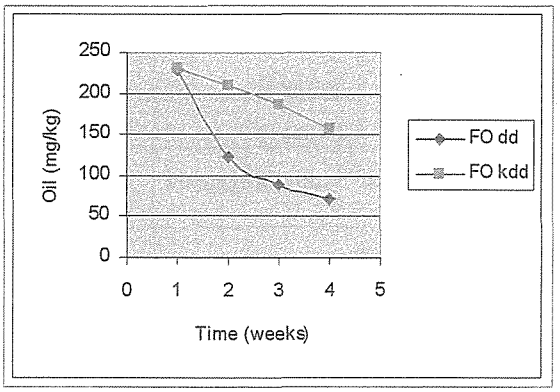


Fig.9 Biodegradation of FO in Can Gio 2

The rate of oil decreasing in the experiment samples No2 (Can Gio 2) was about 34.44% for DO and about 35.92% for FO; while the rate of degradation of oil in the samples No 3 (Longson) was about 13.5% of DO

Table 8. The variation of the content of DO related with the amount of microorganism, N and P in the sample No3

Time		1st Week	Nutrient adding		
		Without nutrient	2nd week	3rd week	4th week
Nutrient	N (mg/l)	4	25.6	37.2	39.2
	P (mg/l)	0.2	4.2	5.3	5.7
Amount of microorganism (CFU/g)		200000	900000	900000	58000
DOdd (mg/kg)		212.3	122.5	117.5	107.9
DO kdd (mg/kg)		214.7	201	174.4	138.1

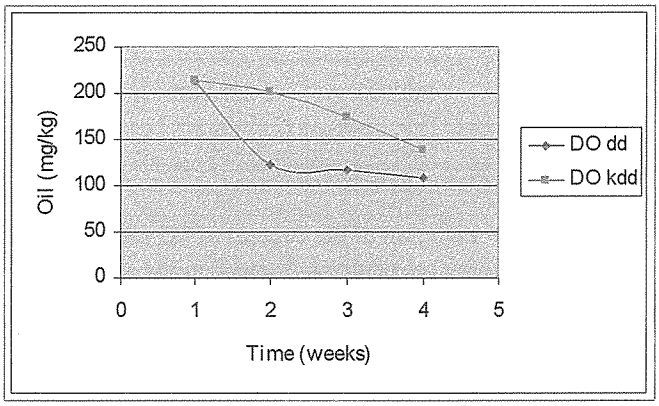


Fig.10. Biodegradation of DO in Long Son

Table 9. The variation of the content of DO related with the amount of microorganism, N and P in the sample No4

Time		1st Week	Nutrient adding		
		Without nutrient	2nd week	3rd week	4th week
Nutrient	N (mg/l)	5	18.2	24.2	27.2
	P (mg/l)	0.5	1.9	2.8	3.4
Amount of microorganism (CFU/g)		72500	160000	8500	117
DOdd (mg/kg)		209.5	137.7	117.0	96.5
DO kdd (mg/kg)		213.2	178.8	126.8	113.6

Table 10. The variation of the content of FO related with the amount of microorganism, N and P in the sample No4

Time		1st Week	Nutrient adding		
		Without nutrient	2nd week	3rd week	4th week
Nutrient	N (mg/l)	5	20.4	28.4	31.4
	P (mg/l)	0.5	2.1	3.2	4.2
Amount of microorganism (CFU/g)		72500	9500	9000	300
FOdd (mg/kg)		225.7	103.5	85.6	67.2
FO kdd (mg/kg)		231.2	163.0	151.0	146.4

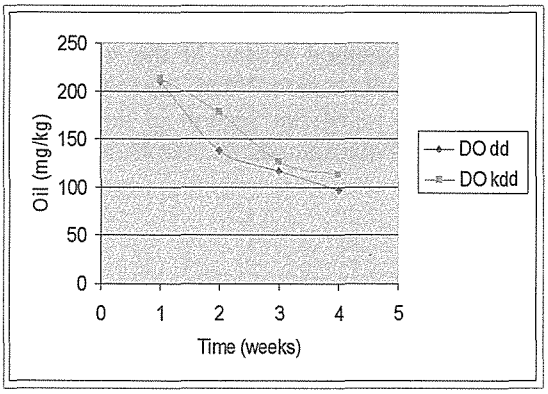


Fig.11. Biodegradation of DO in Vung Tau

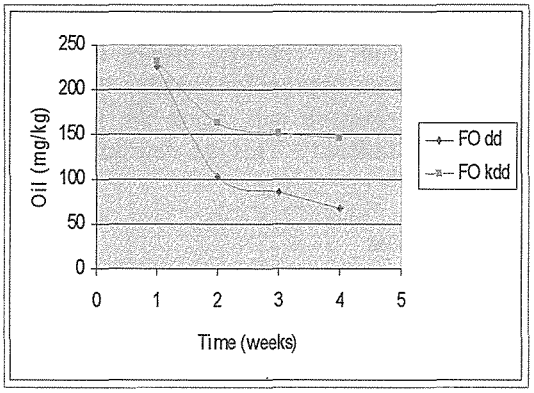


Fig.12. Biodegradation of FO in Vung Tau

In the samples No 4 (Vung Tau) the rate of oil degradation was about 7.2% DO and 33.54% FO

3.3. Discussion

The natural environmental features of the studied area are completely favorable for biodegradation process in oil contaminated shore cleans up.

The amount of oil degrading microorganism in soil is the prior factor in looling for the applying the biostimulation method. Commonly the content of bacteria relates closely with the content of organic matters in sediments. The result of experiment show that although the organic material content in the sediments of the sample No 1, No 2 and No3 are not too different but the amount of oil degrading microorganism vary largely. The highest amount of oil degrading microorganism are found at the position 2 and 3 where always affected by the spilled oil from the accident in Ganh Rai gulf.

The rate of degradation of DO and FO varies place to place. The fact proves that there are several species of oil degrading bacteria in the area and there is the variation of their distribution over the studied area.

With the added nutrient, oil degrading bacterium can increase strongly to urge the biodegradation process.

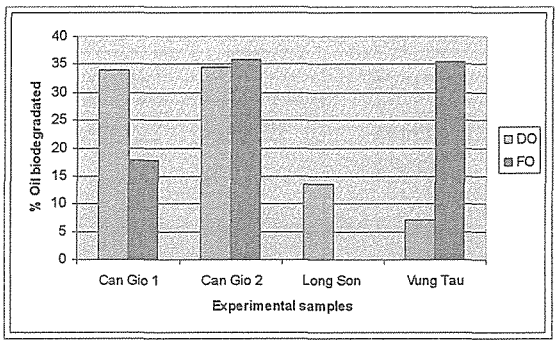


Fig.13. Comparing the rate of oil biodegradation in samples

4. Conclusion

In the contingency plan in response to oil spill hazard for the southern coastal of Viet Nam, it is hard to identify the sacrifice area, especially for Ganh Rai gulf.

The primary result of research proves that the biostimulation method is one of the most promising secondary treatment options for cleaning up the contaminated shorelines from Vung Tau to Can Gio (Ganh Rai gulf). The research can create the possibility of finding a sacrificial section in the area of high environmental sensitivity. This is a new approach of environmental management in petroleum industry

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