Investigation of Coastlines polluted with c-heavy oil spilled from the Nakhodka

INVESTIGATION OF COASTLINES POLLUTED WITH C-HEAVY OIL SPILLED FROM THE NAKHODKA

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ABSTRACT

The damage and recovery of the Japanese coastline from Suzu, Ishikawa Prefecture to Mikuni, Fukui Prefecture was investigated visually over two years after a C-heavy oil spill from the Russian tanker "Nakhodka" in the Sea of Japan on January 2, 1997. The C-heavy oil tended to remain for a long time on bedrock and boulder/cobble/pebble type coastlines but it disappeared rapidly from coastlines of gravel/sand and man-made structures such as concrete tetra-pods. At one year after the accident, among the coastlines of bedrock, the strongest remaining tendency of C-heavy oil was observed on the coastlines of sheltered type. Wave energy appeared to be the main force of cleaning the oil. The contamination was remarkably improved by two years after the accident.

INTRODUCTION

A Russian tanker, the Nakhodka (1,3157 gross tons), which was loaded with 19,000 kl of C-heavy oil, sank in the Sea of Japan approximately 100 km north-north-east offshore from Oki Islands, Shimane Prefecture, Japan on January 2, 1997. Over 6,200 kl of the oil was released from the tanker within a few days, and a part of it reached the Japanese coastline from Shimane Prefecture to Akita Prefecture, Japan by a strong northwest wind. After the accident, many people including volunteers attempted to clean-up the oil energetically and researchers from Japanese national and local governments and universities began an environmental impact assessment. However, these researches were mostly discontinued soon after the accident. No long-term investigations were carried out except for some investigations by local governments (Kizu *et al.*, 1998).

The Nakhodka oil spill was the third largest oil spill occurred in the sea near Japan in recent years. Marine pollutions by large-scale oil spills have counted seventeen including Gulf War in the past thirty-six years since the Tory Canyon oil spill in 1967 till the Prestage oil spill in 2002. The Tory Canyon oil spill brought the international rule to prevent oil contamination. Some long-term environmental impact assessments such as the one for Exxon Valdez oil spill in 1989 (Maki, 1991; Neff and Burns, 1996; Davies and Toppong, 1997; Wells *et al.*, 1997) have bee carried out. However, most of these oil spills were crude oil spills. Little information is available on C-heavy oil spill.

C-heavy oil contains higher concentrations of polycyclic aromatic hydrocarbons (PAHs), asphaltene and resin than crude oil. This gives C-heavy oil a high viscosity recalcitrance, which causes it to remain in the environment for a longer time (Hayakawa *et al*, 1997; Goto *et al.*, 1997). Several PAHs are carcinogenic and/or mutagenic, suggesting that C-heavy oil in an ecosystem can act as a carcinogen and mutagen. In the case of the Blair Corp crude oil spill in the Shetland Islands in 1993, abnormally high concentrations of PAHs were found in blue mussel even three years after the oil spill (Webster *et al.*, 1997). In addition, several PAHs in C-heavy oil show endocrine disrupting activity (Kizu *et al.*, 1999, 2000). This suggests that C-heavy oil spilled from the Nakhodka might have long-term affects directly and indirectly on the ecosystems of both the ocean and the coast. Considering the differences between C-heavy oil and crude oil described above, the impact of C-heavy oil might be different from that of crude oil.

One of the objectives of this study was to assess the damage to different types of coastline from Suzu, Ishikawa Prefecture to Mikuni, Fukui Prefecture, where a large amount of the oil came ashore, 14 and 27 months after the accident. The results were used to determine how coastal characteristics affect the retention tendency of C-heavy oil.

EXPERIMENTAL

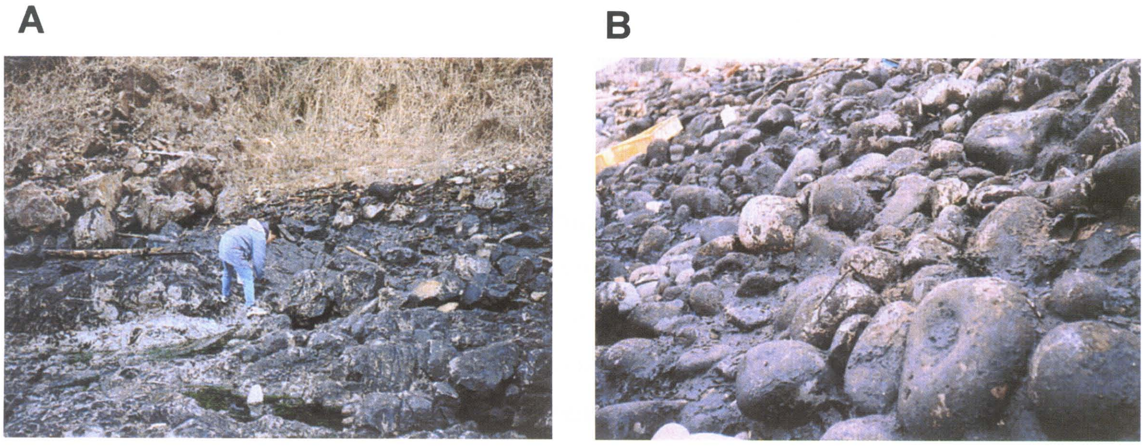

Figure 3 Pictures of typical D-level coastlines on March 5, 1998. (A) Shakuzaki, Suzu (bedrock); (B) Nafune, Wajima (boulder/cobble/pebble).

C-heavy oil tended to remain for a long time on the bedrock and boulder/cobble/pebble coastlines, but was removed rapidly from gravel/sand coastlines, suggesting that the wave power was strong enough to clean-up gravel/sandy coastlines. The oil was removed more rapidly from coastlines made of man-made materials such as concrete tetra-pods, apparently because these structures were always exposed to strong waves. The D-level zones on the bedrock and boulder/cobble/pebble coastlines one and two years after the accident are shown in Figure 4.

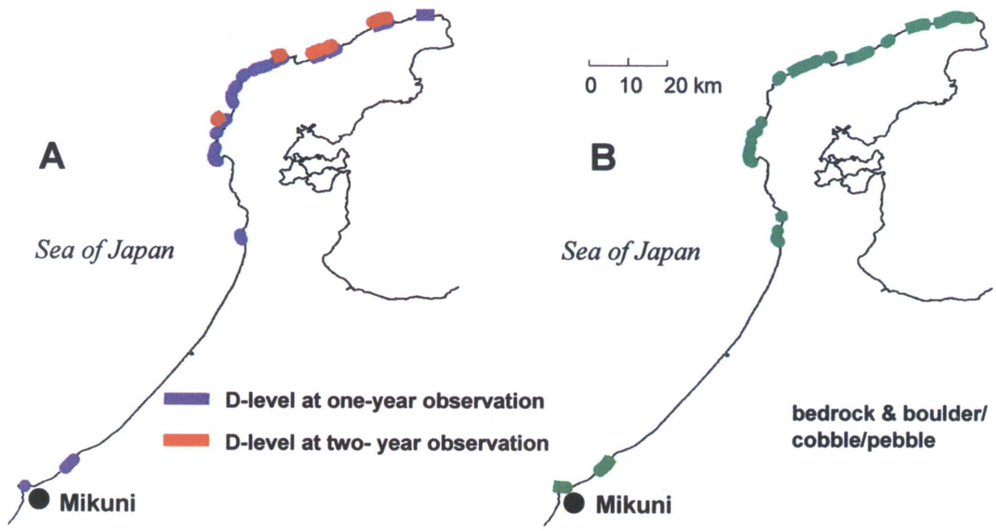

Figure 4 Relationship between (A) coastlines long-term polluted with C-heavy oil and (B) coastlines of bedrock and boulder/cobble/pebble.

The first observation (one-year observation) was done on March 21 and 22 and April 17 and 18, 1998 and the second observation (two-year observation) was done on April 17 and 18 and May 15, 1999. The total length of coastlines visually investigated was 170 km, from Suzu, Ishikawa Prefecture to Mikuni, Fukui Prefecture, except for steep coastlines which could not be reached by walking (Figure 1). The coastlines investigated were divided into 176 zones, and the persistence of C-heavy oil was monitored. The substrates of the 176 zones were classified into 4 types, bedrock (60 zones), boulder/cobble/pebble (particle size $\geqq$ 4 mm, 34 zones), gravel/sand (particle size $<$ 4 mm, 53 zones) and man-made material (tetra-pods, etc., 29 zones). The shapes of the coastlines of bedrock and boulder/cobble/pebble were thoroughly classified into 3 types, exposed (30 zones), pocket (35 zones) and sheltered (32 zones) as shown in Figure 2. The persistence of C-heavy oil was classified into 4 classes, not found (A), rarely found (B), often found (C) and very often found (D).

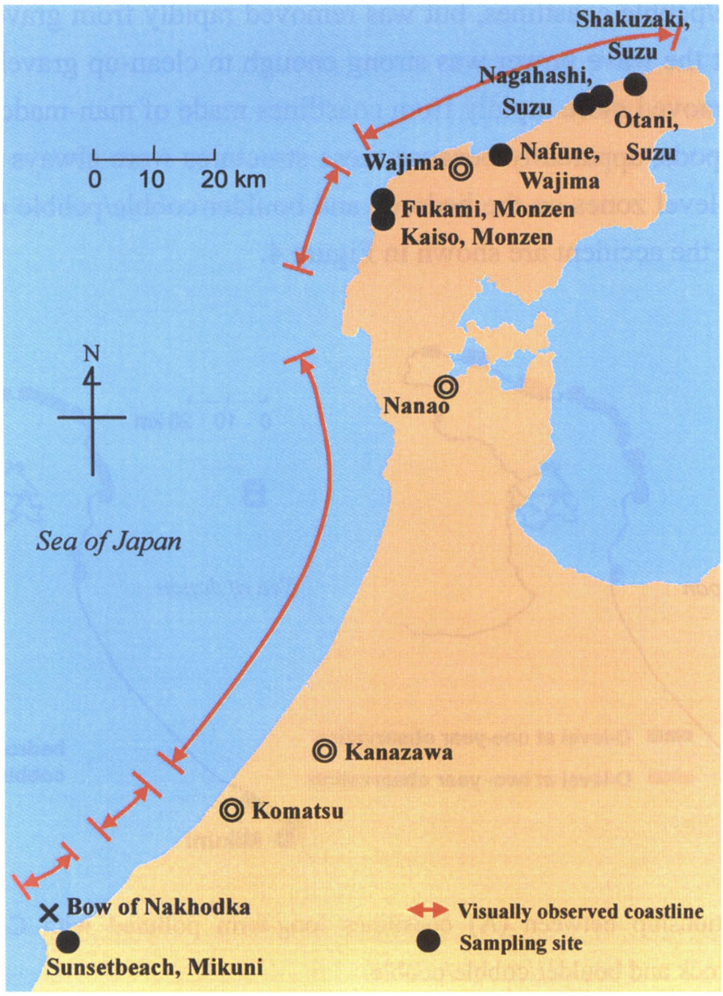

Figure 1 Sampling sites in Ishikawa and Fukui Prefectures.

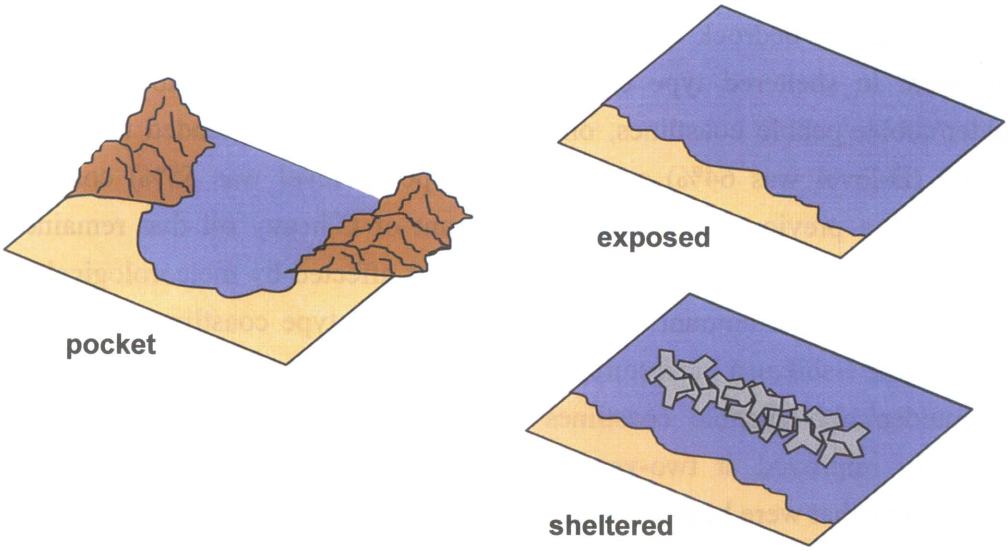

Figure 2 Shapes of coastlines.

RESULTS AND DISCUSSION

Table 1 shows the relationship between substrate types of coastlines and residual tendency of C-heavy oil. One year after the accident (at one-year observation), the percent of the zones that were heavily oiled (D) were high for the types of bedrock (47%), boulder/cobble/pebble (47%) and man-made material (50%), but low (6%) for the type of gravel/sand. One year after the oil spill, both (A) bedrock and (B) boulder/cobble/pebble coastlines were still covered with oil (Figure 3). Two years after the accident (at two-year observation), the ratios of D-level of bedrock, boulder/cobble/pebble and man-made material types were remarkably decreased to 8%, 12% and 0%, respectively (Table 1).

Table 1 Residual level of C-heavy oil of Ishikawa and Fukui coastlines

Substrate type	n	% at one-year observation				% at two-year observation			
		A	B	C	D	A	B	C	D
bedrock	60	29	9	15	47	13	62	17	8
boulder/cobble/pebble	34	12	21	21	47	44	27	18	12
sand	53	59	19	16	6	68	22	4	6
man-made structure	29	31	7	12	50	38	37	25	0

The one-year observation was done on March 21, 22 and April 17, 18, 1998. The two-year observation was done on April 17, 18 and May 15, 1999. A, not found; B, rarely found; C, often found; D, very often found.

Among the bedrock coastlines at one-year observation, the most heavily oiled areas were in sheltered type coastlines (D-level was 61%) (Table 2). Among the boulder/cobble/pebble coastlines, on the other hand, the oil tended to remain on the exposed (D-level was 64%) and sheltered type (D-level was 55%) coastlines. This agreed with a previous report that the amount of C-heavy oil that remained on the bedrock or boulder/cobble/pebble coastlines was affected by meteorological condition, and that the residual amount was small on exposed type coastlines, but large on the sheltered type (Ishikawa Prefecture, 2000). Although the contamination of both bedrock and boulder/cobble/pebble coastlines was serious at one-year observation, it was remarkably improved at two-year observation (The fraction of the zones of each coastline type that were heavily oiled (D) was no more than 14%).

Table 2 Relationship between coastline types and residual tendency of C-heavy oil

Substrate type	Coastline type	% at one-year observation				% at two-year observation			
		A	B	C	D	A	B	C	D
bedrock	exposed	38	0	19	43	11	66	11	11
	pocket	33	16	11	39	0	100	0	0
	sheltered	16	11	11	61	14	56	21	7
boulder/cobble/pebble	exposed	9	9	18	64	62	19	5	14
	pocket	25	17	33	25	0	100	0	0
	sheltered	0	36	9	55	17	33	42	8

The one-year observation was done on March 21, 22 and April 17, 18, 1998. The two-year observation at two years was done on April 17, 18 and May 15, 1999. A, not found; B, rarely found; C, often found; D, very often found.

The different oiling degree suggests that the coastline experienced different intensities of environmental damage. Therefore, classifying the coastline based on the intensity of environmental damage should make it possible to rank this coastline ranking. This is useful to predict where would be polluted and to adopt what kind of recovery method for each type of coastline. The Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration (NOAA HAZMAT of USA) has published “Environmental Sensitivity Index maps (ESI maps)” which describe all elements such as relative exposure to wave and tidal energy, shoreline slope, substrate type and biological productivity and sensitivity (NOAA, 2002). According to the guidelines given on the ESI maps, the fragility of bedrock and boulder/cobble/pebble is higher than that of gravel/sandy beach and the fragility of the sheltered type is higher than that of the exposed type. Our results are in accordance with the guidelines of ESP maps. However, the tendency described in the guidelines for oil to remain on sheltered coastlines than on exposed coastlines was not observed clearly in our investigation.

Several factors might account for the above difference. In winter, a strong northwest wind from Asian Continent hits the west coast of Japan Islands, causing high energy waves to strike the coastline. Therefore, the oil might be easily removed by wave action. However, pocket or sheltered type coastlines (Figure 2) where the waves are usually weak, the oil is not always removed but is removed only during storms. In Noto Peninsula, there are many shield type coastlines where a lot of rocks are observed. On these types of coastlines, the wave energy is always reduced. In addition, because the viscosity of the Nakhodka C-heavy oil is much higher than that of crude oil, the C-heavy oil might resist the cleaning action of waves, suggesting the longer existence of the oil. Moreover, the quick clean-up operation by the volunteer right after the accident was disturbed by other factors of Noto Peninsula: steepness of the coastline, the low population and the slowness of the traffic.

After the Nakhodka C-heavy oil spill, the Ministry of the Environment, Japan began drawing up fragility maps like the ESP maps made by NOAA. The results of this study suggest that in order to rank the coastlines, we must consider not only the coastal shape and substrate type but also the wave energy based on meteorological factors and the type of oil (viscosity).

CONCLUSIONS

After the C-heavy oil spill from the Nakhodka in January 1997, the damage to the coastlines from Suzu, Ishikawa Prefecture to Mikuni, Fukui Prefecture was investigated visually over two years. The following results were obtained.

1) The C-heavy oil tended to remain for a long time on the coastlines of bedrock and boulder/cobble/pebble but was removed rapidly from the coastlines of gravel/sand and man-made structures such as tetra-pods.
2) Along bedrock and boulder/cobble/pebble coastlines, C-heavy oil most remained the longest on sheltered type coastlines.
3) The above tendencies were in accordance with the guidelines of ESP maps.
4) C-heavy oil contamination of the coastlines was remarkably improved by two years after the accident.

Acknowledgement

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