What kind of shoreline in the most dangerous for oiling ?

WHAT KIND OF SHORELINE IS THE MOST DANGEROUS FOR OILING?

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ABSTRACT

Investigations for oil residue have been carrying out at 77 oiled shorelines on *NOTO* Peninsular. This survey is based on "SOS (Shoreline Oiling Summery) Form" developed by Environment Canada. Relations of oil residue and shoreline type, slope, sediment as well as some other factors have been analyzed. As a result, oil residue is strictly depending on following four factors. 1) shoreline sediment, 2) existence of sheltering rocks or wave cuts, 3) width of backshore and 4) slope of shoreline.

INTRODUCTION

It On January 2nd, 1997, Russian tanker named *Nakhodka* was navigating from Shanghais to Petrohabavlovsk-Kamchatski carrying 19,221 kiloliters of heavy C oil cargo. It has passed 27 years after she was built. In addition to aging, poor ship management and inadequate loading, the final trigger of the accident was pulled by the fierce gale of the winter weather of the Sea of Japan (East Sea). She could not bear the bending moment caused by 7 to 8 meters effective wave height and over 30 meters wind speed, she broke into two sections approximately 100 kilometers off Oki Island. Main section sank to the sea floor and bow section was drifting for five days about 250 kilometers, finally grounded at Mikuni Town, Fukui Prefecture (see Figure 1).

By this tanker accident, total about 8,660 kiloliters of oil was pilled. This volume is the second biggest in the Japanese oil spill history. Soon after the accident occurred, Japan Coast Guard announced the spill volume was 6,240 kiloliters as an official figure. But Sao (1998) has pointed out that this does not include the volume while the bow section was drifting and subsequent grounding.

Comparing with world major tanker oil spills, *Nakhodka*'s case has one conspicuous feature: world biggest tanker spill is said to be *Amoco Cadiz* happened in Brittany in France in 1978. In this case, about 270,000 kiloliters of crude was spilled and then some 300 kilometers of shorelines were oiled (NOAA HAZMAT, 1996). On the other hand, *Nakhodka* spilled some 8,600 kiloliters then affected more than 1,300 kilometers of shorelines including over 9 prefectures and 88 cities and towns (Sawano, 1998).

It has already six years passed since the accident, but some coastlines, particularly in *Noto* Peninsular, heavy oil contamination still remains (Sawano, 2003a).

In Japan, some thousand kiloliters or more scaled oil spill has not occurred ever since Mizushima Industrial Complex heavy oil spill happened in 1974. This "fortune" prevented this country from introducing and developing nation-level oil spill response systems including laws system based on modern science and technology (Sawano, 2003b).

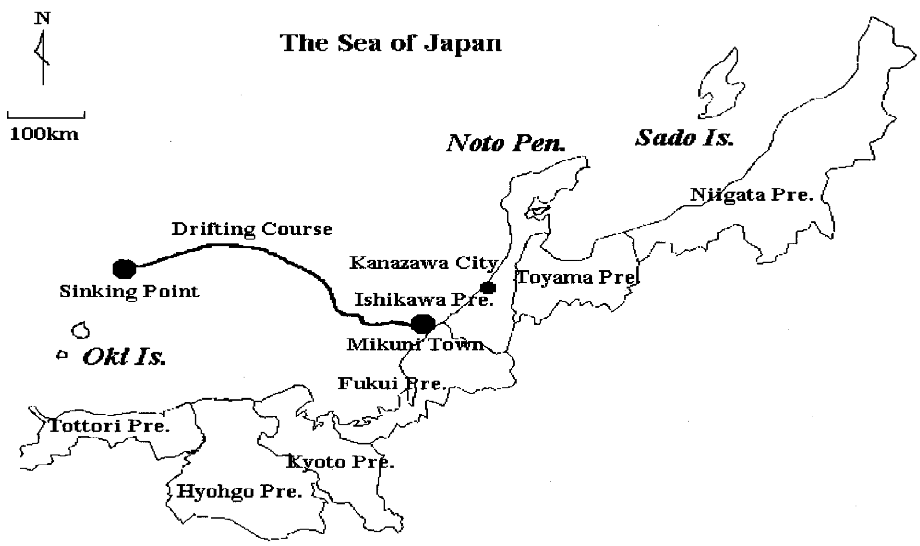

Figure 1. Location of *Nakhodka* Oil Spill

Almost all shorelines of *Noto* Peninsular facing the side of the Sea of Japan ("*SOTO-URA*") were oiled although this peninsular is as much as 200 kilometers apart from the tanker grounded site in Mikuni town. This because heavy weather disturbed recovery works done by mechanical equipment such as oil collection ships and skimmers. Finally, some 6,900 kiloliters of spilled oil is said to be stranded on shorelines (Sao, 1998), and about 2,500 to 3,500 kiloliters thought to be reached *Noto* area (Environment and Security Department of Ishikawa Prefecture, 1998).

On-site surveys for checking and observing the oiling condition have been started since August 1999, 18 months after the spill. Soon after the spill, following two reasons prevented starting the survey.

Noto peninsular has 583 kilometers of various kinds of shorelines; oil pollutions occurred anywhere at the outside of this peninsular. It was impassible to decide the research sites because no one investigated which shoreline got oiled severely. Both city and town government organized recovery works, but these works were done by the local people and the volunteer workers almost spontaneously (Sawano, 1998). Every business diary was so inadequate that it was impassible to identify the exact position of the oiled sites. Once heavy oiled areas could have been identified, shoreline topology of *Noto* Peninsular is too complicated to keep long-term periodic observations on the exact same position.

The first difficulty has been overcome by making interviews to the local people who joined the recovery works. The second has been solved to use GPS (Global Positioning System) and GIS (Geographical Information System) for on-site surveys. Fortunately, Japan Coast Guard has started mid-wave dGPS correction signal broadcast since April 1999, and then precision and accuracy of GPS positioning has been improved extremely. Anyway, it took more than one year to start the on-site research. Figure 2 shows the position of on-site survey.

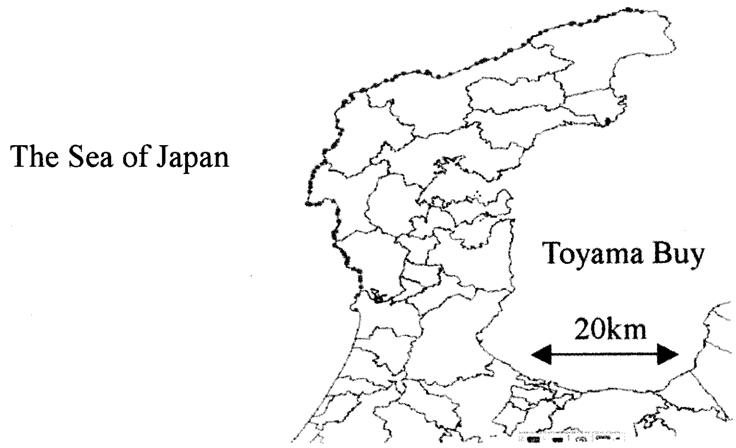

Figure 2. Position of On-site Survey

METHOD

SOS Form

Base on the lessons of numerous numbers of oil spills, “Shoreline Oiling Summary Form” (SOS form) has been developed for 1) make documents with consistent procedure, the oiling conditions and the physio-ecological character of the oiled shorelines, 2) identify and describe human use, ecological and culture resource effects and the constraints on cleanup operations, 3) cross-check pre-existing information on environmental sensitivities or clarify observations from the aerial surveys (Owens and Sergy, 1994).

In this form, “standardized terms” are appropriated for the certain condition of oiling. Table 1 and Figure 3 show the example of the terms and template chart.

Table 1. Standardized Terms in SOS Form

Category	Terms	Oiled Condition
Distribution	Trace (TR)	< 1%
	Sporadic (SP)	1 - 10%
	Patchy (PT)	11 - 50%
	Broken (BR)	51 - 90%
	Continuous (CN)	91 - 100%
Thickness	Pooled (PO)	> 1cm thick
	Cover (CV)	> 0.1cm and = 1cm thick
	Coat (CT)	>0.01cm and = 0.1 cm thick
	Stain (ST)	= 0.01cm thick
	Film (FL)	Transparent or sheen

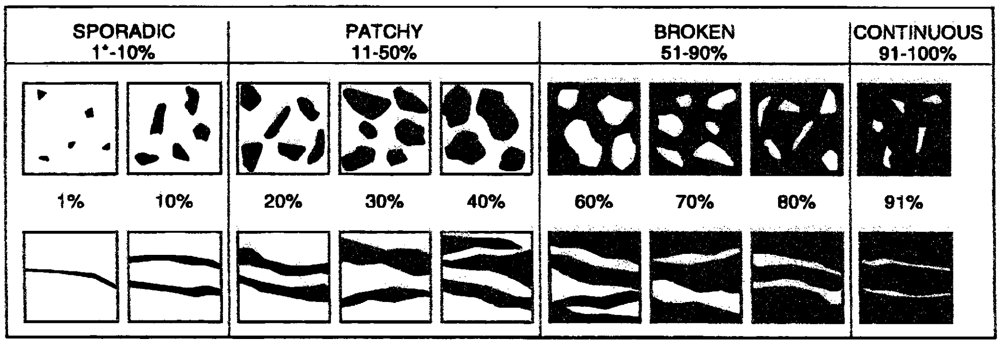

Figure 3. Template Chart for On-site Survey (Owens and Sergy, 1994)

Although the main purpose of this form is not post spill survey, it is helpful to describe and record the condition and changing of oiled sites. Keeping records based on this form, changing of oiled sites with time-series can be aware. However, the purpose of this form includes designing effective recovery works based on the rough estimate of the volumes of remaining oil, it is insufficient to figure out "relative intensity" of each oiled site. To compensate this inconvenience, point scores are appropriated to each standardized terms for both surface and subsurface oil residue (See Table 2).

Table 2. Sores for oiled condition

Surface	Score	Subsurface	Score
Sporadic	10	Trace/Stain(TR,ST)	10
Patchy	20	Cover / Coat(CV,CO)	20
Broken	30	Partially Filled Pores(PFP)	30
Continuous	40	Oil filled Pores(PP)	40
		Asphalt Pavement(AP)	20-40

On actual occasions of on-site monitoring researches, *Shoreline Assessment Job Aid* developed by NOAA has been used to evaluate the oiling condition. Figure 4 and 5 show the example of this job aid and the actual oiled site in *Noto* Peninsular.

Figure 4. An example of Shoreline Job Aid by NOAA
This picture shows the Oil-filled Pores (OP)
Whole pages of this job aid can download from
http://www. http://response.restoration.noaa.gov/oilaids/shore/shore.html

Figure 5. "OP" oiled site in *Noto* Pen., three years after the spill
Oil-filled Pores (OP) can be seen at the study site of *Komedashi, Wajima*.

Table. 3 ESI Classification Criteria by NOAA

ESI Rank	Shoreline Type
1	Exposed Rocky Shores
2	Exposed Rocky Platforms
3	Fine-grained Sand Beaches
4	Coarse-grained Sand Beaches
5	Mixed Sand and Gravel Beaches
6a	Gravel Beaches
6b	Riprap Structures
7	Exposed Tidal Flats
8a	Sheltered Rocky Shores
8b	Sheltered Artificial Structures
9	Sheltered Tide Flats
10a	Salt to Brackish Marshes
10b	Freshwater Marshes
10c	Swamps
10d	Mangroves

http://response.restoration.noaa.gov/shor_aid/shore/shore.html

Classifying Sediment Type

Grundlach and Heys (1978) point out that oil residue depends on the type of shoreline sediment. Comparing with Rocky cliff and boulder shoreline, the latter remains longer than the former: soon after the spilled oil strands on the beach, oil begins to penetrate into subsurface area and filled with the gaps of the sediment. In the case of

The Torry Canyon in England in 1967, Lawn et. al. (1999) reports it took more ten years to remove the oil from the subsurface zones of the shoreline .

The idea that residual period of oil and intensity of environmental influence depends on the type of the sediment has been consolidated into ESI (Environmental Sensitivity Index). Whole study sites of *Noto* Peninsular have classified by ESI rank proposed by Halls et. al. (1997), and Table 3 shows the classification criteria.

Shoreline Slope

Oil residue is also depending on the slope of the shoreline, if the oiled site has 7 degree or steeper slope, and then oil remains longer (Halls et. al., 1997).

Slope is commonly measured by levels, but carrying levels and other land measurement equipment such as tripod are inconvenient on the occasions of on-site monitoring. Then, “Pole and Horizon Method” is used as a simple method and Figure 2 and 3 show this principle. In Figure 3, $h1$ is the height of horizon measured by a staff standing at the water edge, and $h2$ is the eye height of the surveyor. Horizontal length $x1$ has been measured by laser range finder. Mean slope of the vertical section of the shoreline can be calculated by trigonometric function with ease (Sawano, 2001).

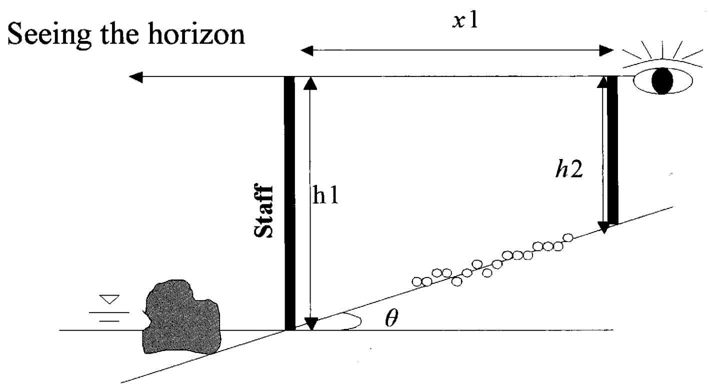

Figure 3. Principle of Pole and Horizon Method

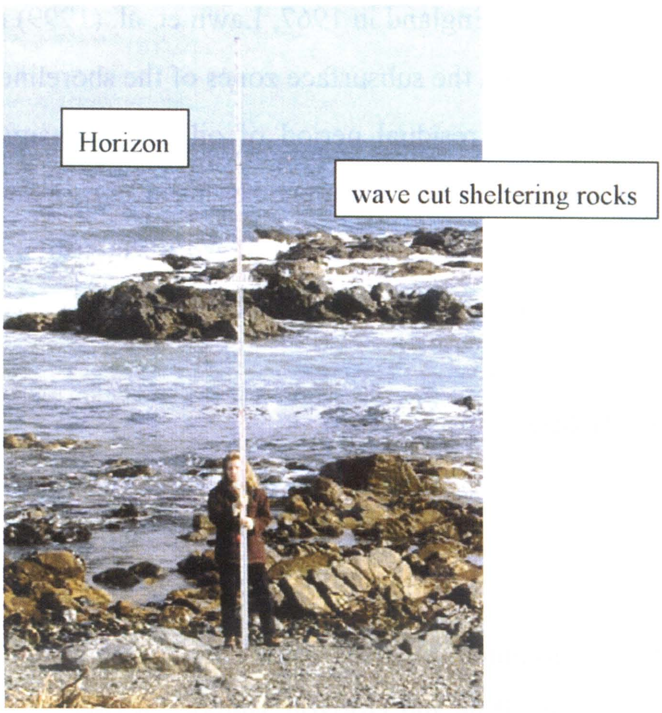

Figure 4. Actual Image of Pole and Horizon Method

Other Parameters

Following parameters have also been surveyed in the on-site monitoring researches. 1. width of backshore (length between the beach face to the top of dune or the rear side of the storm berm), 2. existence of wave sheltering rocks or manmade wave cuts (see Figure 4.) and 3. vegetation.

Results

Relation between Oil residue and Research Parameters

Data obtained in 1999 are mainly analyzed by following research parametric categories because this data is the “newest” from the tanker accident. Results are shown below:

1. ESI rank

Table 4. SOS Score according to the shoreline ESI rank

ESI Rank	Site Num. of Oil Remained	Site Num. of Oil Not Remained	Rate of Oil Residue	SOS Average Score
1,2	3	0	1.0	17.5
3	17	5	0.8	15.0
4	2	2	0.5	10.0
6b,8b	2	2	0.5	16.7
8a	30	5	0.9	35.8

2. Existing of wave cut sheltering rocks and manmade structures

Table 5. Effects of Existence of wave cut sheltering rocks and manmade structures

Existence of Sheltering Rocks	Site Num. of Oil Remained	Site Num. of Oil Not Remained	Rate of Oil Residue	SOS Average Score
Existing	36	9	0.8	34.4
Partially existing	0	1	0.0	0.0
Manmade wave cuts	1	0	1.0	20.0
None	21	2	0.9	16.4

3. Width of backshore

Table 6. Relation between width of backshore and oil residue

Width of backshore	Site Num. of Oil Remained	Site Num. of Oil Not Remained	Rate of Oil Residue	SOS Average Score
less than 10m	3	1	0.8	10.0
10 to 20m	7	1	0.9	29.2
20 to 0m	18	6	0.8	29.2
30 to 40m	19	4	0.8	31.8
40 to 50m	5	0	1.0	22.0
50 to 100m	3	0	1.0	36.7
more than 100m	1	0	1.0	10.0

4. Shoreline Slope

Table 7. Relation between shoreline slope and oil residue

Shoreline slope (degree)	Site Num. of oil Remained	Site Num. of Oil Not Remained	Rate of Oil Residue	SOS Average Score
less than 4	17	6	0.7	23.8
4 to 15	33	8	0.8	17.5
15 to 30	2	0	1.0	10.0
more than 30	2	0	1.0	35.0
almost vertical	2	0	1.0	31.4

DISCUSSIONS

These results are almost correspond to the prior achievements such as Halls et. al (1997), etc. Table 4 shows that 8a (sheltered rocky shores) have higher SOS score because oil has penetrated into the sediment. Moreover, Table 5 shows oil residue occurs irrespective of existence of the sheltering rocks or manmade structures, but it is easily understood that these rocks and structures have roles for preventing oil from washing away from the beaches.

Data shown by Table 6 presents severe oiling will occur only at the shorelines whose backshore width are more than 10 meters. If the width is less than this scale, stranded oil is cleaned from every type of shoreline within a short period of time.

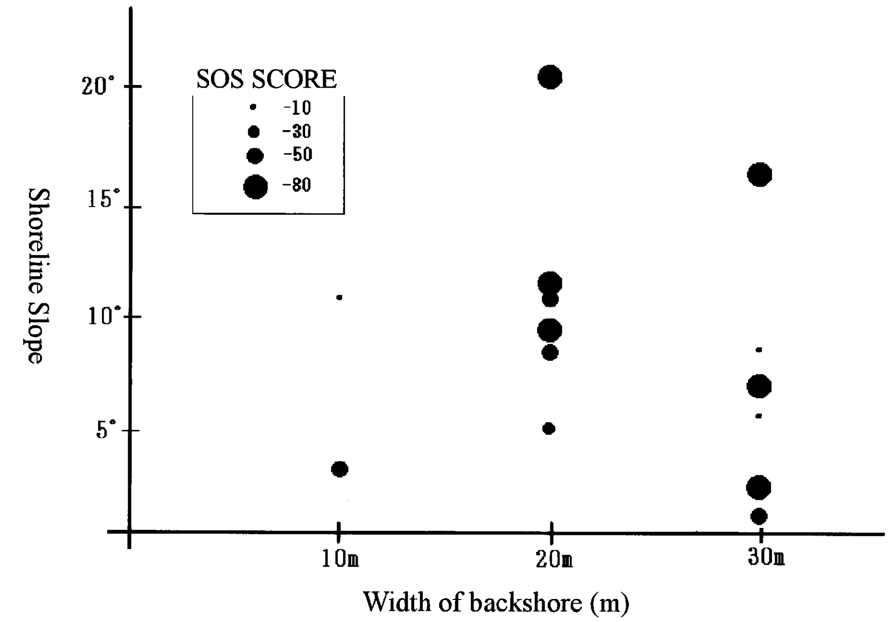

Figure 5. Relation of shoreline slope, width of backshore and SOS score

Figure 5 shows the relation of shoreline slope, width of backshore and SOS score. According to Halls et. al. (1997), shoreline slope and size of sediment have a certain relation. But most Japanese shorelines have concrete bank protections at the rear side of the shore, and then this relation does not always come into effective. This tendency is accelerated when concrete structures are built on the shorelines whose sediment is brittle like andesite. Halls et. al. (1997) also reports cobble and boulder beach have 20 or more degree of mean slope, but most shorelines of this type in *Noto* Peninsular have only 3 to 5 degree. This should be because wave reflection generated by the concrete walls reduces the slope.

CONCLUSION

To summarize above discussions, conclusion will as be follows: oil residue is strictly depending on following four parameters such as 1) sediment, 2) existence of sheltering rocks and manmade wave cuts, 3) scale of backshore and 4) slope of shoreline.

The first key parameter is the width of backshore: if this width is less than 10 meter, no oil will remain for a long time at any kind of shoreline. If backshore width is in the mid-scale as to 20 to 30 meter, the possibility of severe oiling increases: in addition, if the shoreline has 10 degree or steeper slope, this possibility becomes even higher. Comparing with the same size of backshore shorelines, cobble or boulder shorelines are more vulnerable than the others, and if these shorelines have wave cut sheltering rocks, the possibility reaches the highest. In the case of 40 meter or wider backshore shorelines, long-term severe oiling will occur regardless of shoreline slope at rear side of the storm berm or on the foot of the dune slope. If these large-scaled beaches have wave sheltering rocks with cobble or boulder, once oil stranded on these shorelines, it takes the longest time for oil to remove from the shorelines.

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