A case study of geo-pollution about fuel oil

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Abstract Objectives of Phase I investigation of an SS (Service Station) that caused an oil leakage accident are to screen all over the station, confirm the site of leakage, and determine the two-dimensional size of pollution. Phase II is a subsequent closer investigation to elucidate the mechanism of the pollution. Thus, the preciseness of Phase I investigation determines whether the clean-up countermeasure will succeed or not.

In a stratum consisting of sand, silt, and clay layers, the sand layer will be permeated with larger amounts of oil because of its coarseness. Even within a sand layer, oil adhesion varies between fine sand and rough sand. Therefore, sand should further be classified carefully according to the particle size. We have recommended to use a gas monitor in the core analysis, and to analyze every 10-cm segment of the core.

If the mechanism of pollution can be exactly elucidated by surveying strata and groundwater, by installing observation wells, and by identifying the kind of oil concerned, an appropriate clean-up countermeasure will be found out.

1. Introduction

A tanker wreck at sea causes a serious environmental pollution. In March 1989, an oil tanker named EXXON VALDEZ (214,861 DWT) of American nationality was stranded off Alaska, and 20,000 tons of crude oil flowed out, resulting in environmental destruction. On January 2, 1997, the bows of a tanker named NAXДKA (19,684DWT) of Russian nationality was broken off the coast of Shimane Prefecture. A large amount (19,000 kL) of oil fuel of class C that had been loaded in the tanker flowed out, and drifted ashore on the coasts of Hyogo, Kyoto, Fukui, Ishikawa, and Toyama, creating serious difficulties. On July 2, 1997, DIAMONDGRACE, a supertanker (259,999 DWT) that was fully loaded with crude oil, accidentally sustained damage to her bottom off the coast of Honmoku while going up north toward Kawasaki sea berth along the west side of Nakanose. Because of this accident, a large amount of oil, including 1,500 kL of crude oil, flowed out. Thus, an accident on a large tanker causes massive outflow of oil, which drifts and pollutes the sea and coast.

Environmental destruction has occurred in association not only with sea accidents of tankers but also with apparently invisible underground oil leakage. The number of service stations (SS's) in Japan was largest in 1999, and it was more than 55,000. In a half of the SS's receiving Phase I investigation, there was evidence suggesting some oil leakage in the past. If leakage of 0.1 L/day occurs in each SS, the amount of leakage is estimated as 5.5 kL/day, i.e. more than 2,000 kL/year, although it is not realistic to assume that oil leakage occurs in every SS.

We have been addressing the issue of oil pollution. Because oil contains benzene, toluene, ethylbenzene, xylene, etc., we include them in the target substances to be analyzed in the oil pollution investigation. These substances are volatile, but adhere easily to analytical instruments unlike trichloroethylene or tetrachloroethylene, so that special precaution is needed in the on-site analysis. We here report our methods of investigation and cleanup countermeasures while showing some actual examples.

2. Environmental quality standards for oil Pollution

At the end of March in 2002, 2,330 wells in Japan have shown pollution in excess of the environmental quality standards (according to a report from the Ministry of the Environment in December, 2002). Pollutants in excess were volatile organic compounds (VOC's) in 1,554 sites, and benzene only in 15 sites, superficially suggesting that oil pollution was rare. Here, we must consider the details of the pollutant classification. The Ministry of the Environment has specified 15 items of "heavy metals, etc." and 11 items of VOCs in the Environmental Quality Standards for Water Pollutants (Table 1). Among oils, only benzene is regulated as a pollutant, and toluene, xylene, etc. have been specified as substances requiring precautionary monitoring. Business establishments dealing in benzene are regulated as the specified facility, but SS's are not regulated as such although gasoline contains benzene. This seems to explain why the reported number of oil pollution cases was so small as compared with a large number of existing SS's and other potential sources of oil pollution.

Among substances usually contained in oil products, benzene is the only substance regulated by the Environmental Quality Standards, and therefore, determination of benzene concentrations is essential in investigating oil pollution. According to the Standards for Soil Pollution and the Standards for Groundwater Pollution, the concentration of benzene must be 0.01 mg/L or less (If soil is the case, this standard value is applied to the test solution obtained by the specified methods of elution). Benzene is contained in various oil products, and its concentration in gasoline is about 0.5 to 1%. Toluene and xylene in groundwater are not currently regulated by the Environmental Quality Standards. However, they are included in the substances requiring precautionary monitoring, and their guideline values are 0.6 mg/L or less for toluene and 0.4 mg/L or less for xylene. Gasoline also contains these two substances (Table 1).

Table 1 Environmental Quality Standards for Human Health

Heavy metal etc.			VOC's		
	item	Standard value		item	Standard value
1	Cadmium	<0.01mg/l	16	Dichloromethane	<0.02mg/l
2	Total cyan	not detectable	17	Carbontetrachloride	<0.002mg/l
3	Lead	<0.01mg/l	18	1,2-Dichloroethane	<0.004mg/l
4	Sexivalent chrome	<0.05mg/l	19	1,1-dichloroethylene	<0.02mg/l
5	Arsenic	<0.01mg/l	20	cis-1,2-dichloroethylene	<0.04mg/l
6	Total mercury	<0.0005mg/l	21	1,1,1-Trichloroethane	<1mg/l
7	alkyl mercury	not detectable	22	1,1,2-Trichloroethane	<0.006mg/l
8	Selenium	<0.01mg/l	23	Trichloroethylene	<0.03mg/l
9	Fluorine	<0.8mg/l	24	Tetrachloroethylene	<0.01mg/l
10	Boron	<1mg/l	25	1,3-dichloropropene	<0.002mg/l
11	simazine	<0.003mg/l	26	Benzene	<0.01mg/l
12	thiobencarb	<0.02mg/l	Monitored Substances and Guideline Values		
13	thiuram	<0.006mg/l		toluene	<0.4mg/l
14	nitrate-N and nitrite-N	<10mg/l		xylene di (2-ethylhexyl) phtalate	<0.06mg/l
15	P C B	not detectable		and others (19 Categories)	

Source: Environment Agency

Some countries also regulate ethylbenzene, MTBE (methyl tertiary-butyl ether), an octane number improver, total petroleum hydrocarbons (TPH's), and polycyclic aromatic hydrocarbons (PAH's). Standard values have not yet been specified for TPH's or PAH's in Japan, but will be specified in the future as in Europe and America. TPH's in strata are determined by appropriately combining two methods of extraction (solvent shaking extraction and high temperature, high pressure solvent extraction) and two methods of assay (gas chromatography and infrared spectroscopy).

The U.S. Environmental Protection Agency (U.S.EPA) has stipulated that in quantitative estimation of TPH's, they should be separated into gasoline range organics (GRO's) corresponding to C_6 to C_{10}, and diesel range organics (DRO's) corresponding C_{11} to C_{28}.

Organics corresponding to C_{29} to C_{44} are usually estimated as lubricating oil range organics although EPA has not specified this class.

3. Forms of oil pollution

Oil is lighter than water and only slightly soluble in water. Accordingly, oil pollution occurs predominantly in forms of adhesion to the vadose zone and floating on the surface of groundwater. Leaked oil goes down to the surface of groundwater according to the terrestrial

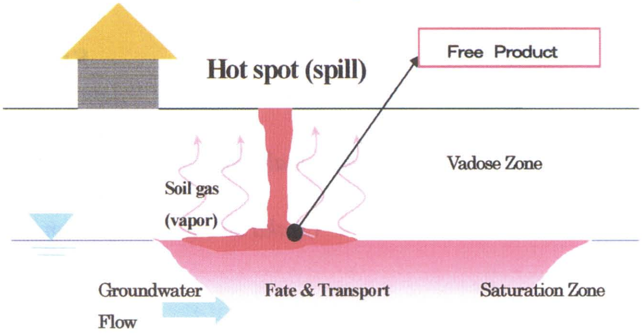

Fig. 1 Forms of oil pollution

gravitation, and spreads over the water because of its low specific gravity. The body of pollutants occurs near the surface of groundwater as a mass of oil concentrated in capillary zone. Such masses are referred to as "free products". A part of the oil dissolves in groundwater, diffuses along the stream of water, and accumulated usually in a relatively shallow part of the groundwater (Fig. 1).

A fact-finding investigation needs surface pollution investigation, core boring, and trial boring to confirm the existence and state of free products as well as oil penetration into strata.

4. Oil pollution investigation

Oil pollution investigation is conducted at a site where oil pollution of soil and/or groundwater is suspected (e.g. SS's dealing with gasoline and other oils). As the state of pollution is different from site to site, investigation and analysis suitable to the individual site should be designed and conducted.

The kind of oil that we deal with in this paper mainly includes light-gravity oil (gasoline, kerosene, jet fuel) and medium-gravity oil (light oil). As for heavy-gravity oil, investigation should specially be designed because it is poorly volatile.

4-1. Procedures of investigation

Investigation for site assessment is conducted stepwise from Phase I to Phase Ⅳ. Fig. 2 shows its flow chart.

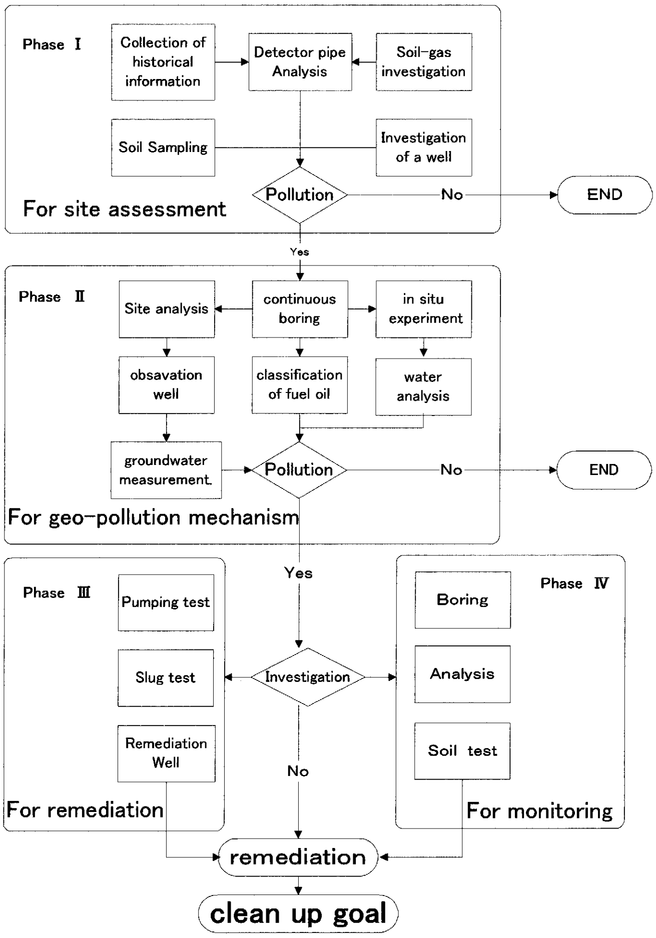

Fig. 2 flow chart investigation and remediation of geo-pollution

4-2. Methods of investigation (General survey)

4-2-1. Feasibility study

The first step of site assessment in the oil pollution investigation is to investigate the geologic history of the site, in which the use of the land is retrospectively investigated. Old topographical maps, aerial photographs, ancient maps, geologic maps, Land Condition Map, land registration records, and other necessary documents are collected in advance, and the possibility of pollution is previously assessed by reviewing topographical history and the way of land use.

In the on-site survey, detailed topographic features are confirmed, and the surrounding environment is reconnoitered. Furthermore, the administrative person of the site is interviewed for items necessary for environmental assessment, e.g. underground installation, amounts of oil they deal with, state of administrative affairs, history of accidents, and methods of inspection.

- Site history (history of land use, history of changing underground tanks, accident history, operation procedures at the service station, etc.) and its surrounding receptors (drinking water wells, surface water, underground storage sites for goods for common profit, waste water drains, etc.)
- Layout diagrams indicating the location of underground tanks, piping, measuring instruments, oil/water separators, wells, etc.
- Evidence suggesting oil leakage (discoloration of strata, poor plant growth, leakage from containers, inventory shortage, etc.)
- Geology and hydrogeology of the site-surrounding area, and the level and flow direction of groundwater

If it is considered to be appropriate from the results of the on-site investigation, the subsequent steps of investigation are planned.

4-2-2. Detector tube investigation

In SS's having underground tanks, a detector tube is installed in each of the 4 corners of the tank without exception. If oil leaks from the tank, the leak enters into the tube. Therefore, a detector stick is inserted into the tube at regular intervals to detect possible leakage. In the on-site investigation, these tubes are used for gas detection. If there is an oil leak in the tube, the tube is saturated with gas even if the leakage is minimum. Thus, oil leakage, if any, can be detected by measuring the gas concentration by a gas monitor. In case groundwater is found in the tube, the water is sampled and analyzed on site. The results are to be included in the fundamental data that will be used for the subsequent screening.

If this on-site analysis reveals a toxic chemical in excess of the Environmental Quality Standards or other standards, laboratory analysis is performed when appropriate.

4-2-3 Soil gas investigation

The target of the detector tube investigation is underground tanks, but soil gas investigation is carried out to detect leakage from underground piping, stationary measuring instruments, and oil/water separators. Practical purposes of this investigation are to detect underground penetration by volatile oils, to detect the place of leakage, and to confirm the extent of underground oil leakage.

The procedures are as follows. The SS area is plotted out (usually, into 5-meter squares). A hole of 0.85-meter depth is dug at each intersecting point, and underground air is sucked and analyzed by a gas monitor (Fig. 3). Holes in which a high concentration of gas is detected are further investigated by using GC/PID (a portable gas chromatograph) (Fig. 4).

Two methods of soil gas investigation are available: one is Kimitsu's method (Figs. 3 and 4), and the other is the ground air system method (Fig. 5) in which underground air is forcedly sucked without ground destruction. Usually, Kimitsu's method is used because the surface of SS's is covered with concrete.

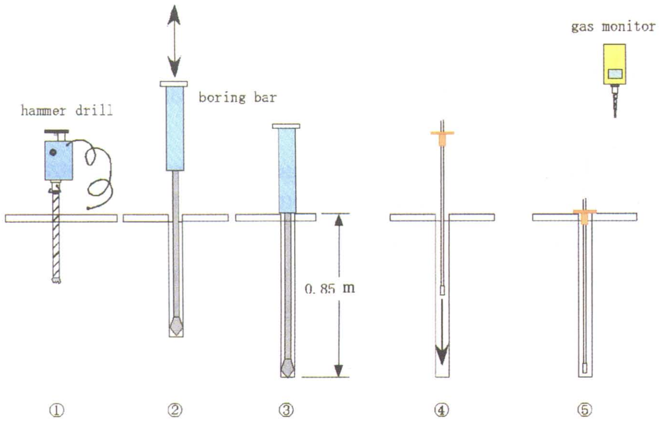

Fig. 3 Soil gas investigation using PID gas monitor

① If the floor has been concreted, use a hammer drill and make a hole. (Step 1)
② Bore a hole vertically into the ground with a boring bar. (Step 2)
③ Bore down to a prescribed depth (0.85 m). (Step 3)
④ Insert a gas sampler Teflon tube into the bore. (Step 4)
⑤ Collect a gas sample from a prescribed depth, and measure the gas concentration with the PID gas monitor. (Step 5)

This method is simple, not time-consuming, and on-site measuring of underground TVOC gas concentrations. Components of the gas sample are analyzed on site with GC/PID (Fig. 4). The target gases are benzene, toluene, ethylbenzene, and xylene (BTEX).

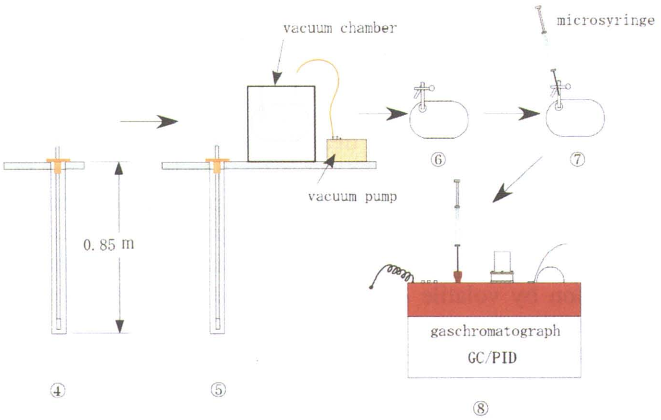

Fig. 4. Analysis using GC/PID

④ Insert a gas sampler Teflon tube into the hole.
⑤ Using a vacuum pump, collect gas samples from a prescribed depth into a tedlar bag (PVF film bag).
⑥ Take out the tedlar bag from the vacuum box.
⑦ Using a microsyringe, take a1000-μl aliquot of the gas from the vacuum box.
⑧ Analyze the sample by gas chromatography.

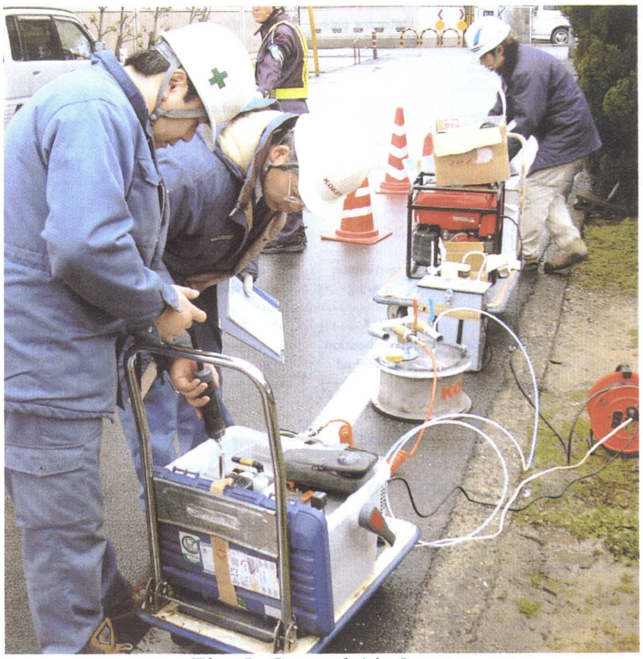

Fig. 5. Ground Air System

4-2-4. On-site screening of groundwater

When groundwater is found in a detector tube installed in the underground tank, samples are collected, and analyzed with a gas monitor. If the result is positive, BTEX components are analyzed by GC/PID. Adequate care should be devoted to selecting an appropriate method of groundwater sampling so that contamination is prevented.

The groundwater sampling tube should be changed to new one at each time of sampling to avoid contamination.

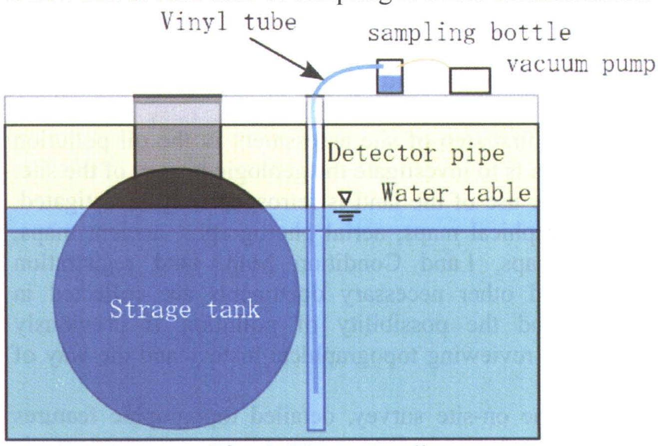

Fig. 6. Water sampling

4-3. Methods of investigation (Close survey)

In this chapter, methods of a close survey of pollution will be described.

4-3-1. Boring survey

Various methods of boring are available: auger boring, percussion penetration method, rotary percussion method, hollow stem auger boring, and mechanical boring. An appropriate method is selected according to the depth to be investigated and purposes of the boring. Points to be sampled are decided by using a measuring tape and/or plane-table surveying. The altitude is estimated by leveling. A nearby bench mark is used. If it is not available, a tentative bench mark is set up on an immovable point, e.g. a building.

The diameter of excavation by which samples for geological analysis are collected is to be 86 mm or more. The depth of excavation is decided so that silt and clay layers under the first water-bearing layer can be sampled.

Samples are serially collected, and a total amount of VOC gas is determined with the PID gas monitor for each 10-cm segment. At the depth where the highest VOC gas concentration was detected, component analysis using GC/PID is carried out. The components to be analyzed are BTEX, representatives of noxious volatile oil compounds. Fig. 7 outlines an example of mechanical boring systems.

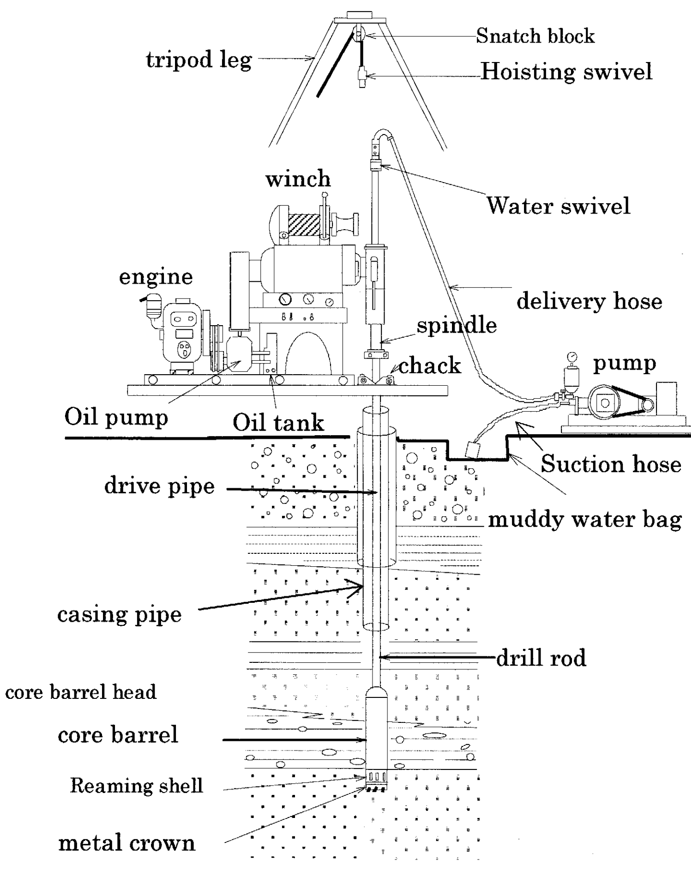

Fig.7 Schematic illustration of mechanical boring

4-3-2. Laboratory analysis

Samples for laboratory analysis are selected from the excavated core by the following criteria:

1. Samples showing the highest total VOC gas concentration in the boring core .
2. Samples containing free products;
3. If neither 1 nor 2 is the case, samples from the layer right above the groundwater.

Laboratory analysis includes the following.

Boring core elution test→ for BTEX and Pb

Content measurement in the excavated core

→ for Pb, n-hexane-extracted substances, and TPH's

Groundwater analysis

→ for BTEX, Pb, n-hexane-extracted substances, TPH's.

Oil leakage from pipe lines or underground tanks is suspected if a VOC gas concentration as high as several thousands of ppm is detected, or if free products are found in the excavated core. In such a case, 2 to 3 samples are collected from the point showing high concentrations of VOC gas, or from the layers lying above and under the free products, and the kinds of oil involved (gasoline, light oil, kerosene, waste oil, etc.) are determined through TPH's analysis, gas chromatography/distillation, TLC/FID, and PAH analysis.

4-3-3. Installation of underground observation wells

After the end of boring survey, underground observation wells are installed for monitoring groundwater pollution. Adequate clearance surrounding the well casing should be left to insert a filter material. Ideally, the width of the clearance is to be a double size or more of the outer diameter of the casing.

Fig. 8 shows a schematic structure of an observation well.

(1) As a well casing, use a polyvinyl resin pipe or PVC pipe with an inner diameter of 50 mm.
(2) Polyvinyl resin joints are to be screw-cut in preparation for recovering the pipes in the future when the well may come into disuse.
(3) Arrange the screen segments and non-pored segments of casing according to the geologic state.
(4) The porosity of the screen is to be 3% or more.
(5) Use a screen of slit-type (Fig.9). A strainer type is not suitable when a free product exists.
(6) Place the screen so as to cover the whole vertical length of the water-bearing layer.
(7) Wrap the screen-bearing portion of the casing with a stainless steel net to prevent the filter material or some other materials from flowing into the well.
(8) As the filter, use equally sized granules with 3 to 5 mm of diameter.
(9) Place bentonite pellets onto the upper surface of the filter material, and make cementing on the surface of the bentonite pellet layer.
(10) Thoroughly wash the inside of the well after the casing was inserted.
(11) Estimate the height of the opening (the top of the casing) by leveling, and enter the value in the well chart.

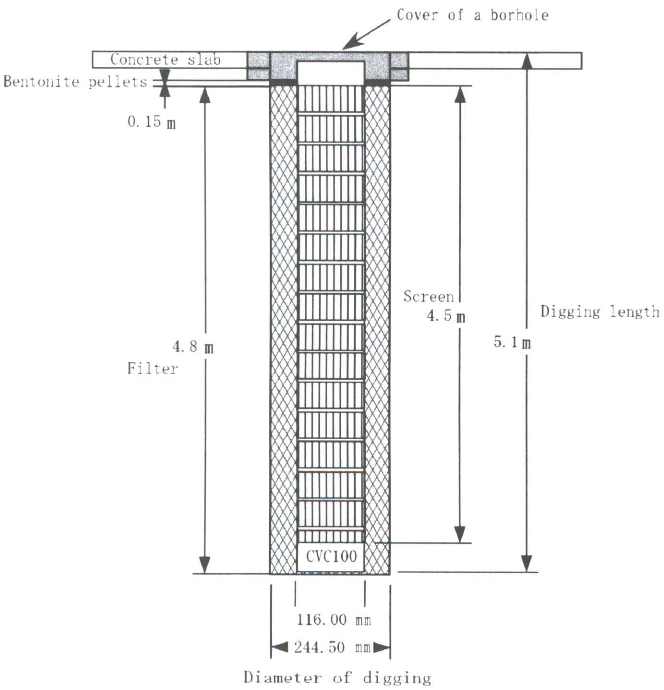

Fig. 8 schematic structure of an observation well

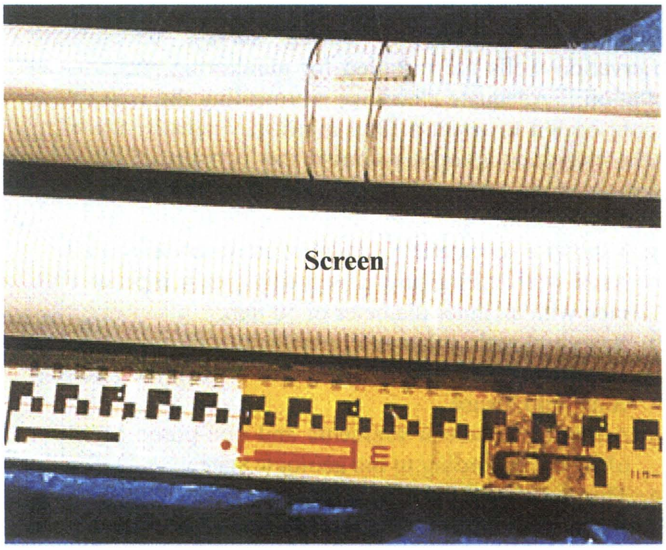

Fig. 9 Casing and Screen

4-3-4. Level and quality of groundwater

In order to investigate a possible change in groundwater and spread of pollution, the level and quality of groundwater in the observation well are monitored. The groundwater level is measured by using the level of the top of the casing as the standard. If a free product exists in the borehole, its thickness is measured, and the measured thickness is subtracted from the measured groundwater level to obtain the corrected value of the level.

The items to be measured are the water level in the hole (borehole?), thickness of free products, and existence of oil slick. If natural attenuation (NA) is to be included in the cleanup countermeasure, the following parameters are measured to evaluate its effect:

1. pH, 2. Water temperature, 3. Electric conductivity
4. Dissolved oxygen, 5. Oxidation-reduction potential
6. Nitrogen, 7. Phosphorus, 8.Manganese, 9. Iron
10. Methane, 11. Sulfates, 12. Carbonates.

5. Oil pollution investigation

A case of Phase I and Phase II investigation:

If pollution is suspected from the results of prior investigation, soil gas investigation is carried out. Fig. 10 shows a case of investigation of an oil leakage site.

Phase I investigation of this case judged that there was oil leakage from the tubing running from the distal inlet of the tank as well as the tubing running to the meter.

The phase II assessment three-dimensionally investigates the polluted area identified by the Phase I assessment, and elucidates the mechanism of pollution. When geologic samples are analyzed, special attention is needed. Gasoline, kerosene, light oil, and lubricating oil are less volatile than VOC's (excluding gasoline). If once they adhere to sampling bottles or sensors, they cannot easily be washed out, and may cause estimation troubles or make the analytical instruments unusable. Oils, especially oil products , are less lighter than water, and therefore, they are likely to heavily pollute groundwater surface (Uesuna, et al. 2001). Close observation of core samples is recommended because the presence of oil pollution of the sample can easily be confirmed visually. When the core is immersed into water, oil slick will appear if the core has been polluted with oil. This phenomenon will contribute to the assessment.

In a stratum consisting of sand, silt, and clay layers, the sand layer will be permeated with larger amounts of oil because of its coarseness. As a result, striped oil pollution is frequently observed in alternation strata consisting of sand and silt. Even within a sand layer, oil adhesion varies between fine sand and coarse sand. Therefore, sand should further be classified according to the particle size.

Volatile oils such as gasoline and light oil may massively be retained on the surface of groundwater. Because this oil load depresses the groundwater level, it is recommended to install an observation well, measure the water level and oil thickness at the same time, and adjust the measured water level for the depression by oil load. Such adjustment is necessary when different observation wells are compared with one another.

At a site where light non aqueous phase liquids (LNAPL's) and dens non aqueous phase liquids (DNAPL's) exist in combination, they dissolve in each other, and pollution may extend to a deep layer of the stratum under the influence of DNAPL's.

Polluting oil products are differentially retained in different layers according to their geological characteristics (sand, gravel, clay, etc.). Therefore, sampling and sample analysis should carefully be carried out. The extent of oil adhesion also varies somewhat among fine, middle, and rough sand particles. A close on-site analysis is required for the oil pollution investigation (Fig. 10).

Fig. 11 shows an example of boring core analysis conducted at a site of oil pollution.

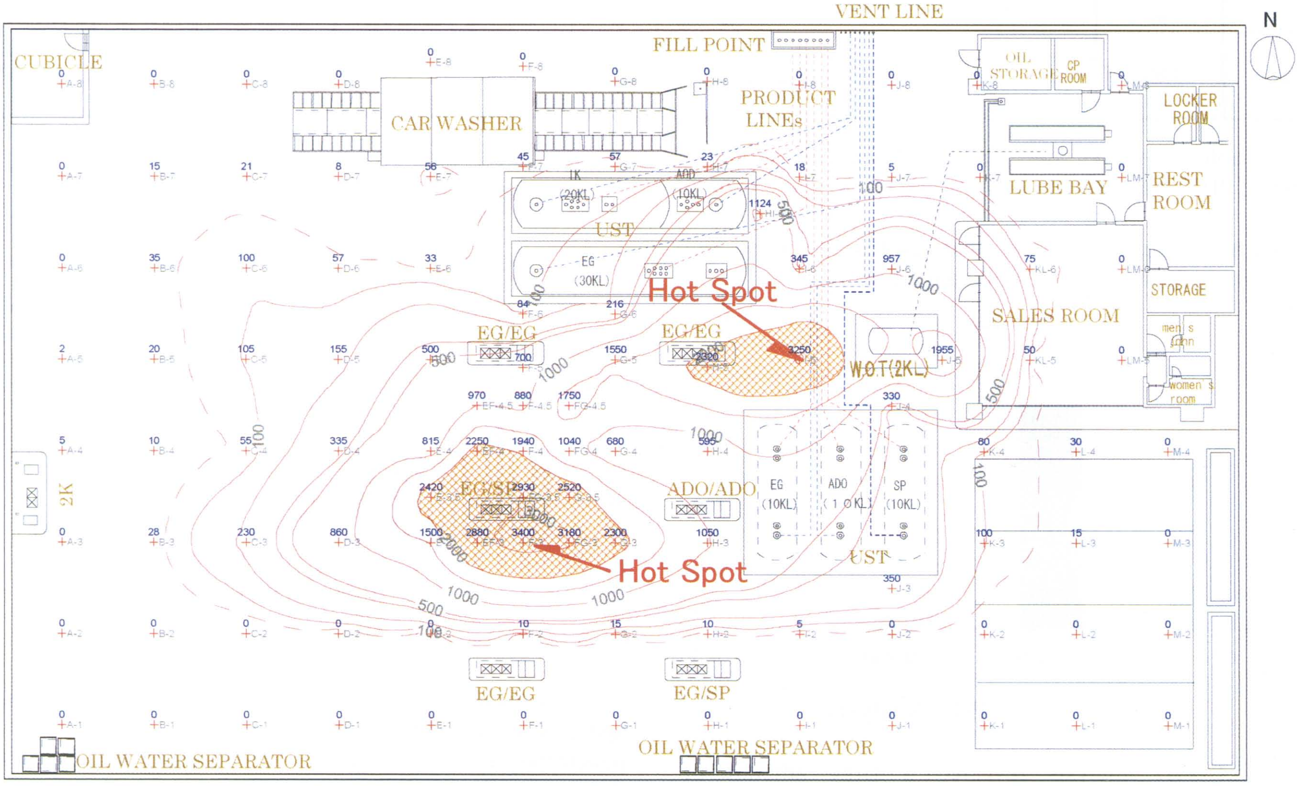

Fig.10 Soil gas Investigation (KIMITSU Method)

Every 10-cm segment of the core sample was analyzed by using a gas monitor. It was revealed that sand and gravel layers retained high concentrations of oils, and that the amount retained varied according to the particle size of the sand. The two highest concentrations of oil lied with the groundwater level between, illustrating a characteristic pattern of LNAPL's pollution. According to our experience in oil pollution investigations, most of underwater heavy pollution is found 1.5 to 2.0 m below the groundwater level.

SS's have a lot of underground tanks containing gasoline, light oil, kerosene, lubricating oil (waste oil tank), etc. Oil leakage from underground tanks or pipe lines can be detected by surface pollution investigation or core boring, but the kind of oil cannot be identified by on-site GC/PID analysis.

Gas chromatography/distillation analysis or TLC-FID analysis (e.g., iatroscan analysis) is used to differentially determine what kinds of oil are responsible for, and elucidate the mechanism of oil leakage. In the case shown in Fig.11, the pattern of oil pollution is well demonstrated, but does not give information about what oils were responsible. In such a case, it is further necessary to sample heavily polluted strata, and analyze the kind of oil involved.

At the site No. A, samples for oil analysis were taken from the depth (GL-1.8 m) at which the highest concentration of oil was detected.

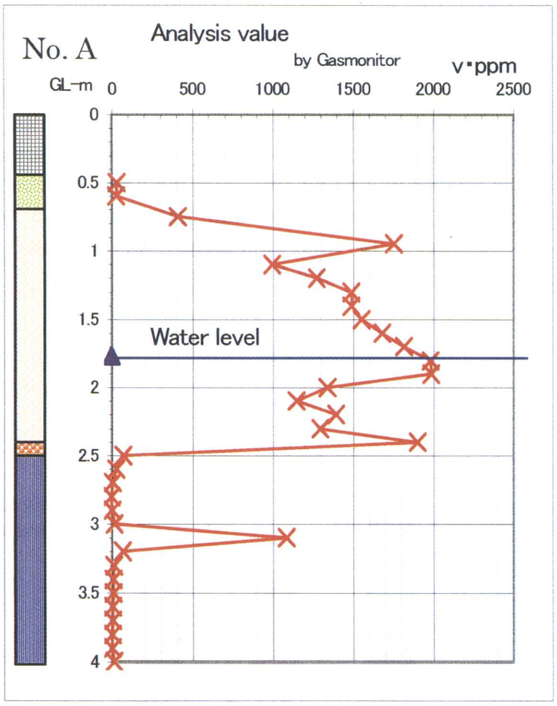

Fig.11 core analysis result example

Table 2. Results of oil analysis

	depth m	analysis method	analysis result(g/kg)			analysis result			
			C_6-C_{10}	C_{10}-C_{28}	C_{28}-C_{44}	saturation	aromatic	resin	asphalten
No.A	1.85	TPH	11	12.4	0.798				
		TLC-FID				38.50%	30.20%	16.70%	14.60%
		GC Distillation	Pollution by gasoline , kerosene and diesel						

Table 2 shows the results of the oil analysis. Among TPH's, fractions of C_6 to C_{10} and C_{10} to C_{28}

Showed high values, suggesting that gasoline, kerosene, and light oil were the responsible pollutants (Fig. 12).

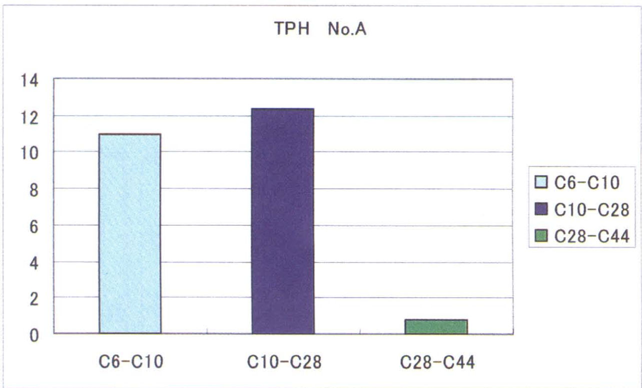

Fig.12 Result of TPH's Analysis

TLC-FID analysis revealed a large amount of saturated organics and aromatic components, suggesting that gasoline and kerosene may be involved in this pollution (Fig. 13). This sample contained resins at about 15%. Usually, resins are not contained in gasoline or light oil. They were probably formed as a result of time-related deterioration of oils. Thus, it seemed that a relatively long time had passed since the underground penetration of pollutant oils occurred.

The detected asphaltene probably originated from coal tar used as an anticorrosive for underground tanks. It seemed likely that anticorrosive coal tar was accidentally dissolved in gasoline or other oils. The positive detection of asphaltene may have suggested that gasoline tanks were somehow damaged or that kerosene was erroneously overflowed in the process of oil supply.

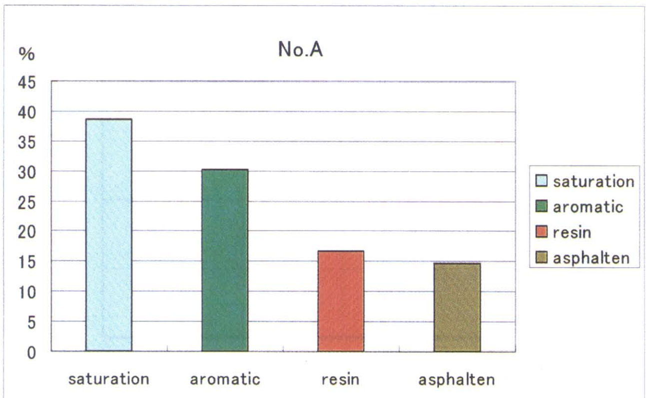

Fig.13 Result of TLC-FID Analysis

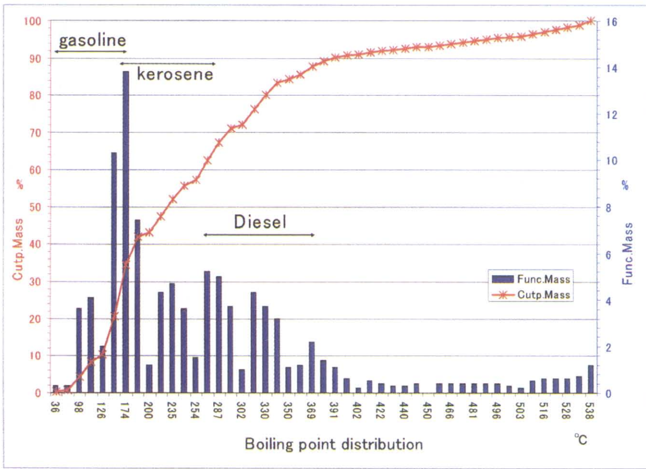

Fig.14 Result of GC Distillation Analysis

Fig. 14 shows the results of gaschromatograph/distillation analysis conducted to closely examine the kind of oil penetrating into the stratum. The fractions distilled at 174 degrees or lower indicate gasoline as a pollutant; those distilled between 170 and 250 degrees indicate kerosene; and those distilled between 240 to 350 degrees indicate light oil. As shown in Table 2, this analysis revealed that the pollutants in the site examined were gasoline, kerosene, and light oil.

6. Countermeasures against oil pollution

The principal point to be considered in taking countermeasures against oil pollution is the fact that the material is combustible. Actually, excavation and incineration are frequently used for cleanup. When gasoline is massively leaked, however, these measures produce a considerable offensive odor and a large amount of volatile benzene released. Safety management for protecting occupational health damage is essential. Moreover, it is also important in designing resident safety measures and cleanup procedures to pursue prior investigations without arousing anxiety among the residents. In oil leakage accidents, groundwater/underground air purification using double casing and ultrahigh pressure washing method were both effective in recovering soil gases and benzene that had dissolved into groundwater from the free products. In the former procedure, double casings are constructed for the well, and soil gases and groundwater are pumped from the outer and inner casings, respectively, to recover benzene, toluene, etc (Uesuna, 2000). In the latter procedure, air and high pressure water of 40 to 200 Mpa are jetted in combination from the drill rod to recover oils having adhered to the stratum as well as benzene, toluene, etc. having dissolved in groundwater (Uesuna, Yamamoto, and Tanaka, 2001).

Volatile oils can be treated similarly to VOC's, but needs special consideration. Because of their strong combustibility, pumps, blowers, and other motors must be of explosion-proof type. At a site polluted with oils, suction and activated charcoal adsorption of underground air may elevate the temperature so high that explosion may happen. Therefore, it is desired that the sucked concentrated gases (1000v・ppm or more) are treated with a combustion chamber, for example, an modified engine.

In the cleanup of a site polluted with oils, it is extremely difficult to estimate the amount of recovered oil because oil is not a single substance unlike trichloroethylene or tetrachloroethylene. Petroleum is a general term given to combustible natural oil liquids (crude oil) and their purified products, and contains hydrocarbons (compounds of carbon and hydrogen) as main components as well as compounds of oxygen, nitrogen, sulfur, etc. as contaminants. Petroleum is separated into gasoline, kerosene, light oil, heavy oil, etc. depending on the boiling point. The only way to estimate their amounts recovered is to convert the measured values into the amount of gasoline based on the MSDS (Material Safety Data Sheet) information given by manufacturers of petroleum. However, even this way of estimation is not useful if considerable amounts of volatile components (benzene, toluene, xylene, etc.) have already escaped in vapor. Because these volatile components are lighter than water, most of them accumulate above the groundwater level, and therefore, a considerable amount may escape in vapor from the ground surface depending on the atmospheric pressure. Thus, the method for estimating the amount of vaporized components remains to be investigated.

7. Conclusion

Idle (or unused) grounds left after closing of service stations are now increasing. SS's do not come under the specified facilities using toxic substances (defined in Article 2, Paragraph 2 of the Water Pollution Control Law <Law No. 138, 1970>), but oil pollution of the strata may exist. In some cases, surplus soil from excavation for a form and essence change of land contains mineral oil, benzene, etc. in excess of the corresponding standard values, and their acceptance may be refused by the prearranged recipient. In other cases, benzene dissolved in groundwater may deteriorate the surrounding environment.

As a result of the growing interest in the global environment such as groundwater and geologic conservation, the soil pollution control law was put in force on February 15, 2003. Thus, the legal regulation for geologic environment has been becoming tightened now. In order to manage the environmental risk of geo-pollution, the lands of which geo-pollution is suspected should exactly be identified. Accordingly, an investigation of such lands is conducted as a matter of duty when a factory or business establishment is closed or when the purpose of its use is changed.

The enforcement of the law will increase the number of pollution investigation, but satisfactory anti-pollution measures cannot be carried out unless the behavior of toxic substances and the state of their existence are definitely confirmed. Moreover, the pollution investigation has become more sophisticated and more diversified year after year. Thus, the geo-pollution mechanism must precisely be elucidated, and appropriate countermeasures should be carried out according to the target of cleanup. The persons who take charge of pollution investigation should be experts who have technical backgrounds supported by much experience at many polluted sites. It seems necessary to train engineers as excellent technical experts based on a qualification system.

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