

Study on the Biodegradability of Dispersants and Dispersant/Bunker-C Oil Mixtures and the Dissolved Oxygen Consumption in the Seawater(II)

— The Biodegradability of Dispersant/Bunker-C Oil Mixtures and the Dissolved Oxygen Consumption in the Seawater —

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The biodegradation experiment, the TOD analysis and the element analysis for dispersant, Bunker-C and dispersant/Bunker-C oil mixtures were conducted for the purposes of evaluating the biodegradability of dispersant/Bunker-C oil mixtures and studying the consumption of dissolved oxygen with relation to biodegradation in the seawater.

The results of biodegradation experiment showed the mixtures with 1:10~5:10 mix ratios of dispersant to 4mg/l of Bunker-C oil to be 0.34~2.06mg/l of BOD₅ and to be 1.05~5.47mg/l of BOD₂₀ in natural seawater.

The results of TOD analysis showed 1mg of Bunker-C oil to be 3.16mg of TOD.

The results of element analysis showed the contents of carbon and hydrogen to be 87.3 % and 11.5% for Bunker-C oil, respectively, but nitrogen element was not detected in Bunker-C oil.

The biodegradability of dispersant/Bunker-C oil mixture shown as the ratio of BOD₅/TOD was increased from 3% to 11% as a mix ratio of dispersant to 4mg/l of Bunker-C oil changed from 1:10 to 5:10, and the mixtures were found to belong in the organic matter group of low-biodegradability.

The deoxygenation rates(K₁) and ultimate oxygen demands(L₀) obtained through the biodegradation experiment and Thomas slope method were found to be 0.072~0.097/day and 1.113~6.746mg/l for the mixtures with 1:10~5:10 mix ratios of dispersant to 4mg/l of Bunker-C oil, respectively. The ultimate oxygen demand of mixture was increased as a mix ratio of dispersant to Bunker-C oil changed from 1:10 to 10:5. This means that the more dispersants are applied to the sea for Bunker-C oil cleanup, the more decreases the dissolved oxygen level in the seawater.

Introduction

It was pointed out that the treatment operations for the oil spilled at sea in Korea were mainly dependent on the oil spill dispersants especially in case of the large-scale oil spills or the oil pollution accidents requiring the urgent control(National

Maritime Police ROK, 1987). It is, however, undesirable to use a large quantity of dispersants for the oil cleanup at sea without discreet consideration(Society for the study of Tanker Oil Pollution, 1976; National Maritime Police ROK, 1987).

In general, it has been known that the application rate of dispersants to oil at sea would normally

be 20~30% of the oil spill quantity (Society for the study of surfactant, 1986). But the application rates are different, depending on the types of dispersants. The treatment rates for oil at sea would normally be one part dispersant to 2~3 parts of oil for the conventional hydrocarbon-base dispersant which may be used undiluted at sea from spray sets using breaker boards or other suitable means of application and agitation and the water-dilutable concentrate dispersant which may be used after dilution 1:10 with sea water and sprayed from spray sets using breaker boards or other suitable means of application and agitation, or one part of dispersant to 20~30 parts of oil for the concentrate dispersant which may be used undiluted from aircraft, ships or on beaches, using appropriate spray gear (Institute of Petroleum, 1986). While Dewling *et al.* (1971) introduced in their paper the US regulations and the Schedule of dispersants and other chemicals to treat oil spills published as national contingency plan in June 1970, which stipulate the restrictions on use of dispersant for pollution control purposes and which prescribe that no dispersant shall be applied in quantities exceeding 5 ppm in the upper 3 feet of water column during 24-hour period and in no case, except special cases, will the daily application rate of chemical exceed one-fifth of total volume spilled, and they emphasized that dispersant biodegradability was important when a decision was made regarding the use of dispersant for oil spill cleanup and from the standpoint of water quality, there must be concern for the rate of degradation and ultimate oxygen demand of dispersant and/or dispersant-oil mixture. However, they did not present any data regarding the biodegradation rates and ultimate oxygen demands of dispersant-oil mixtures in their paper.

There were considerable studies regarding oils or dispersants in Korea such as the oil degradability by oil-degrading microorganisms in various environmental conditions (Kim *et al.*, 1987), the composition change of Bunker-B oil treated and mixed with dispersants (National Maritime Police ROK, 1987), the degradation of oil by microorganism (Lee *et al.*, 1985; National Maritime Police ROK, 1990), the emulsion of water-in-oil (Kang *et al.*, 1991), etc..

However, there has not been any study in Korea regarding the biodegradability of Bunker-C oil treated with dispersant and its relation with the dissolved oxygen consumption in seawater. Lee *et al.* (1990) also pointed out that the study of oil biodegradation rates would be necessary to be made for the development of oil biodegradation model.

In an attempt to investigate the biodegradability of Bunker-C oil treated with dispersant and the dissolved oxygen consumption in relation to the biodegradation in seawater, the TOD analysis and the element analysis were conducted for the dispersant and the Bunker-C oil which was a main kind of oil spilled frequently in Korean coastal waters, and the biodegradation experiment was performed for dispersant/Bunker-C oil mixtures in natural seawater as well.

Materials and Methods

1. Materials

Dispersant

The trade name of dispersant for experiment was SEAGREEN 805A which passed the test and was approved to be fit for the criteria of dispersant efficiency (KMPA, 1979; Korean Industrial Standards, 1984) by Korea Maritime and Port Authority. The dispersant, SEAGREEN 805A is referred to as SG hereinafter.

Bunker-C oil

The properties of Bunker-C oil used in experiment are shown in Table 1. Bunker-C oil is referred to as BC hereinafter.

Surfactant

The trade name of surfactant for experiment was KONION OA-5, one of nonionic surfactants that could be a component of dispersant, of which water content was 0.5%, HLB was 9.1, composition was Polyoxyethylene oleyl ether and formula was $\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COO}(\text{CH}_2\text{CH}_2\text{O})_5\text{H}$. The Surfactant, KONION OA-5 is referred to as OA5 hereinafter.

Natural seawater

The natural seawater used in experiment was sampled off the coast of Busan, Korea in May 1991,

Table 1. Properties of Bunker-C oil(MF-180) used in experiment

Specific gravity (API)	Kinematic viscosity (50 °C, Cst)	Pouring point (°C)	Flash point (°C)	Sulfur content (%)	Water content (%)
17.3	170	-2	92	-	0.05

immediately transferred to the laboratory and analyzed. The properties of natural seawater are given in Table 2.

Table 2. Properties of natural seawater used in experiment

Items	Values	Items	Values
Temp.(°C)	16.5	NH ₄ ⁺ -N(mg/l)	0.30
pH	8.1	PO ₄ ³⁻ -P(mg/l)	0.02
Salinity(‰)	34.21	TSS(mg/l)	4.00
NO ₂ ⁻ -N(mg/l)	0.10	VSS(mg/l)	1.10
NO ₃ ⁻ -N(mg/l)	0.30	COD(mg/l)	1.10

2. Methods

1) Determination of biodegradation

Prior to experiment, natural seawater was filtered through 50~60 μm mesh net. Dispersant samples of which concentration was 4.0mg-SG/l in natural seawater were used to determine the biodegradation of dispersant(SG). The samples of dispersant/Bunker-C oil mixtures(SG+BC) with mix ratios of 1:10, 2:10, 3:10 and 5:10, of which concentrations were (0.4mg-SG+4.0mg-BC)/l, (0.8mg-SG+4.0mg-BC)/l, (1.2mg-SG+4.0mg-BC)/l and (2.0mg-SG+4.0mg-BC)/l, respectively in natural seawater, were used to determine the biodegradation of mixtures. The biochemical oxygen demand (BOD) was used for the determination of biodegradation and BOD was obtained by determining dissolved oxygen in each sample which was stored with blank sample of natural seawater at 20°C in incubator for 20 days.

2) TOD analysis

Total Oxygen Demand Analyzer(IONICS Model 225) was used for the TOD analysis of dispersant (SG), nonionic surfactant(OA-5) and Bunker-C oil

(BC) under the following conditions.

Furnace temperature: 900°C

Air Pressure: 27 psig

Carrier gas, primary nitrogen flow: 0.12 CFH

Carrier gas, secondary nitrogen flow: 120 bubbles/min.

Using 1000mg/l of Potassium biphthalate(C₆H₄(COOK)COOH) stock solution and distilled water, standard solutions were made and the concentrations of 50mg/l, 100mg/l, 250mg/l, 500mg/l and 750mg/l were used for calibration.

Using 1000mg/l of glucose(C₆H₁₂O₆) stock solution and distilled water, standard solutions were made and the concentrations of 50mg/l, 100mg/l, 250mg/l, 500mg/l and 750mg/l were used for verification.

The concentrations of samples for OA5, SG and mixtures in distilled water were 100mg-OA5/l, 100mg-SG/l, (100mg-OA5+100mg-BC)/l, (10mg-SG+100mg-BC)/l, (20mg-SG+100mg-BC)/l, (30mg-SG+100mg-BC)/l and (50mg-SG+100mg-BC)/l, respectively for TOD analysis.

3) Element analysis

CHN CORDER(YANAGIMOTO Model MT-2) was used for the element analysis of dispersant (SG), nonionic surfactant(OA5) and Bunker-C oil (BC) under the following conditions.

He rotameter: 180cc/min

O₂ rotameter: 7cc/min

Heating furnace temperature: 500°C

Combustion furnace temperature: 800°C

2.0mg of Antipyrine(C₁₁H₁₂ON₂) standard substance was used for the unit value of calibration(μg/mm) and each of samples weighed 1.5mg and was analysed.

4) Estimation of biodegradability

Each biodegradability of dispersant(SG) and dispersant/Bunker-C mixtures(BC+SG) was expressed as the ratio of BOD₅ to TOD or BOD₅/TOD

(Inoue, 1972).

5) Deoxygenation rate(K_1) and ultimate oxygen demand(L_0)

The deoxygenation rates and the ultimate oxygen demands of dispersant(SG) and dispersant/Bunker-C mixtures(BC+SG) were calculated using Thomas slope method(Thomas, 1950).

Results and Discussion

1. Biochemical oxygen demand(BOD)

1) Biodegradability by microorganisms in natural seawater

A mixture of 150mg glucose/l and 150mg glutamic acid/l was used as a standard check solution and its BOD was found to be 217.0mg/l, which was very similar to 197 ± 30.5 ppm shown in Standard Method(APHA-AWWA-WPCF, 1989) and to 220 ± 10 ppm presented by Takemoto *et al.*(1978) .

2) BOD of dispersant

The BOD values of 4.0mg-SG/l for 20 days were shown in Table 3 and Fig. 1 and were converted in the unit of mg-O₂/mg-SG and shown in Table 3 as well. The BOD₅ and BOD₂₀ of dispersant(SG) were 0.595mg-O₂/mg-SG and 0.855mg-O₂/mg-SG, respectively and were found to be a little higher than the respective values of 0.410mg-O₂/mg-dispersant and 0.799mg-O₂/mg-dispersant presented by Dewling *et al.*(1971). It means that while the dispersant is degraded by microorganisms in the seawater, plenty of dissolved oxygen can be consumed.

3) BOD of dispersant/Bunker-C oil mixtures

The BOD values of dispersant/Bunker-C oil mixtures(SG+BC) with mix ratios of 1:10, 2:10, 3:10 and 5:10 for 20 days were shown in Table 4 and Fig. 1.

The BOD₅ values of (0.4mg-SG+4.0mg-BC)/l, (0.8mg-SG+4.0mg-BC)/l, (1.2mg-SG+4.0mg-BC)/l and (2.0mg-SG+4.0mg-BC)/l were 0.34mg/l, 0.94 mg/l, 1.22mg/l and 2.06mg/l, respectively and The BOD₂₀ values of (0.4mg-SG+4.0mg-BC)/l, (0.8mg-SG+4.0mg-BC)/l, (1.2mg-SG+4.0mg-BC)/l and (2.0mg-SG+4.0mg-BC)/l were 1.05mg/l, 2.09mg/l, 3.52 mg/l and 5.47mg/l, respectively.

From Table 3, the BOD₅ and BOD₂₀ values of 0.4

Table 3. Biochemical oxygen demands of dispersant (4.0mg-SG/l) in mg/l and in mg-O₂/mg-SG

Day(t)	BOD(mg/l)	BOD(mg-O ₂ /mg-SG)
3	1.51	0.378
5	2.38	0.595
7	2.52	0.630
10	2.94	0.735
20	3.42	0.855

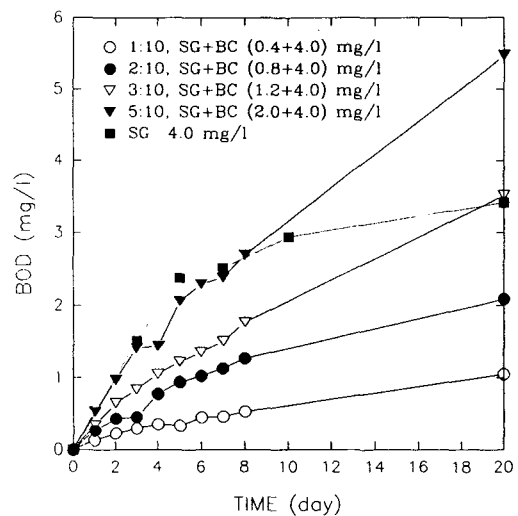


Fig. 1. BOD curves of dispersant(SG) and mixtures (SG+BC).

mg-SG/l could be induced to 0.238mg/l and 0.342 mg/l and those of 1.2mg-SG/l could be induced to 0.714mg/l and 1.026mg/l, respectively, considering only dispersant(SG). The BOD₅ and BOD₂₀ values of (0.4mg-SG+4.0mg-BC)/l were higher than those of 0.4mg-SG/l and the BOD₅ and BOD₂₀ values of (4.0mg-BC+1.2mg-SG)/l were much higher than those of 1.2mg-SG/l. This means that the more dispersant(SG) is applied to the constant quantity of Bunker-C oil(BC) at sea, the more increases the BOD of mixture(BC+SG) or the more can the level of dissolved oxygen decrease in the seawater. The reason is that the BOD value of mixture(BC+SG) is derived from the combination of BOD for dispersant and BOD for Bunker-C oil(Gatellier *et al.*, 1973).

Table 4. Biochemical oxygen demands of mixtures(SG+BC) in mg/l

Day(t)	Mixtures			
	10:1	10:2	10:3	10:5
	SG+BC (0.4+4.0) mg/l	SG+BC (0.8+4.0) mg/l	SG+BC (1.2+4.0) mg/l	SG+BC (2.0+4.0) mg/l
1	0.13	0.27	0.35	0.54
2	0.23	0.44	0.66	0.97
3	0.30	0.46	0.84	1.41
4	0.36	0.78	1.05	1.44
5	0.34	0.94	1.22	2.06
6	0.46	1.03	1.36	2.30
7	0.47	1.13	1.51	2.39
8	0.54	1.27	1.77	2.70
20	1.05	2.09	3.52	5.47

2. Total oxygen demand(TOD)

The results of TOD analysis for glucose, surfactant(OA5), dispersant(SG) and dispersant/Bunker-C oil mixtures(SG+BC) were given in Table 5.

The mean TOD values for each 100mg/l of glucose, OA-5 and SG were 107.1mg/l, 245.1mg/l and 280.0mg/l, respectively. The mean TOD value for (100mg-OA5+100mg-BC)/l of surfactant/Bunker-C oil mixture(OA5+BC) was 561.0mg/l. The mean TOD value of Bunker-C oil(BC) was obtained from the calculation which subtracted the mean TOD value of surfactant(OA5) from that of mixture(OA5+BC) and the TOD value for 100mg/l of Bunker-C oil was found to be 315.9mg/l. On the other hand, The mean TOD values for (10mg-SG+100mg-BC)/l, (20mg-SG+100mg-BC)/l, (30mg-SG+100

mg-BC)/l and (50mg-SG+100mg-BC)/l of mixtures (BC+SG) were 346.1mg/l, 370.6mg/l, 401.5mg/l and 453.4mg/l, respectively. The relative error for all mixtures(SG+BC) with mix ratios of 10:1~10:5 between the analyzed TOD values and the calculated TOD values, which were based on the analyzed TOD values of dispersant(SG) and Bunker-C oil(BC), was within the range of 0.6% and this means that dispersant(SG) and Bunker-C oil(BC) were well mixed in mixture samples and Bunker-C oil was dispersed evenly in water by dispersant.

As shown in Fig. 2, the TOD values for each 1mg of glucose, nonionic surfactant(OA5), and dispersant(SG) were found to be 1.07mg, 2.45mg, and 2.80mg, respectively, and the TOD value for 1mg of Bunker-C oil was also found to be 3.16mg and to

Table 5. Total oxygen demands of glucose, surfactant(OA5), dispersants(SG), mixture(OA5+BC) and mixtures (SG+BC) in mg/l

	Glucose	Surfactant	Dispersant	Mixture	Mixtures				
					10:10	1:10	2:10	3:10	5:10
					OA5+BC (100+100) mg/l	SG+BC (10+100) mg/l	SG+BC (20+100) mg/l	SG+BC (30+100) mg/l	SG+SG (50+100) mg/l
	100	OA5 100	SG 100						
	107.5	239.5	280.0	557.5	343.5	372.0	402.5	454.0	
TOD	106.5	249.0	276.5	565.5	345.0	369.0	402.5	452.5	
(mg/l)	107.2	246.5	283.0	560.0	348.5	370.5	400.0	450.5	
	107.0	245.5	280.5	561.0	347.5	371.0	401.0	456.5	
Mean	107.1	245.1	280.0	561.0	346.1	370.6	401.5	453.4	

be similar to 3~4mg of oxygen which was required for the complete oxidation of 1mg of petroleum hydrocarbon to CO₂ and H₂O (ZoBell, 1969; Gatellier *et al.*, 1973).

The ThOD (Theoretical Oxygen Demand) value for 1mg of nonionic surfactant (OA5) was calculated from the formula and found to be 2.42mg, and comparing with 2.45mg of TOD, the relative error of surfactant (OA5) between ThOD and TOD was found to be 1.24%. No difference between TOD and ThOD was found in glucose. Therefore, it was possible to suppose that TOD agreed with ThOD for all samples.

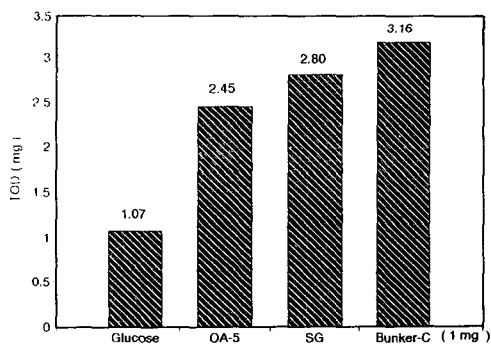


Fig. 2. TOD values per each 1mg of glucose, surfactant (OA5), dispersant (SG) and Bunker-C oil.

3. Element analysis

The contents of carbon and hydrogen were found to be 65.26% and 10.28% for surfactant (OA5), 76.48% and 12.23% for dispersant (SG) and 87.30% and 11.52% for Bunker-C oil (BC), respectively, and nitrogen was not detected in all samples as shown in Table 6.

The theoretical component percentages which were calculated from the formula of surfactant (OA5) were 66.90% for carbon and 10.38% for hydrogen, and the relative error between the theoretical and the analyzed component percentages were found to be 2.45% for carbon and 5.08% for hydrogen.

4. Biodegradability

The biodegradabilities for dispersant (SG) and

Table 6. Element analysis of surfactant (OA5), dispersant (SG) and Bunker-C oil (BC)

(Unit: %)			
Element	OA-5	SG	BC
C	65.26	76.48	87.30
H	10.28	12.23	11.52
N	ND	ND	ND

Table 7. Biodegradabilities of dispersant (SG) and mixtures (SG+BC) shown as BOD₅/TOD in unit of %

Dispersant	Mixtures			
	1:10 SG+BC	2:10 SG+BC	3:10 SG+BC	5:10 SG+BC
SG	2.98	6.32	7.63	11.29
21.25				

dispersant/Bunker-C oil mixtures (SG+BC) in natural seawater shown as BOD₅/TOD were presented in Table 7.

The biodegradability of dispersant (SG) was 21.25% and dispersant (SG) belonged in the organic matter group of middle-biodegradability according to the classification of organic matters defined by Inoue (1972), who investigated biochemical degradabilities of various organic matters using the BOD values and classified organic matters into three groups, or a group of high-biodegradability in case of the value of BOD₅/ThOD being more than 40%, another group of middle-biodegradability in case of 10~40% and the other group of low-biodegradability in case of less than 10%.

The biodegradability of (10mg-SG+100mg-BC)/l was 2.98% and similar to that of aniline being 3% (Okasawa, 1970), the biodegradabilities of (20mg-SG+100mg-BC)/l and (30mg-SG+100mg-BC)/l were 6.32% and 7.63%, respectively, and similar to that of cellulose being 7% (Okasawa, 1970), and the biodegradability of (50mg-SG+100mg-BC)/l was 11.29% and similar to that of methylethylketone being 13% (Okasawa, 1970) which indicates barely middle-biodegradability. On the whole, the biodegradabilities for mixtures (SG+BC) with the mix ratios of 1:10~5:10 were found to be 3~11% and to be similar to those of urea and benzene investi-

gated by Kim and Park(1982). Generally speaking, the mixtures with 1:10~5:10 mix ratios of dispersant to Bunker-C oil were found to belong in an organic matter group of low-biodegradability.

The biodegradability for mixture(SG+BC) was increased from 2.98% to 11.29% as the mix ratio changed from 1:10 to 5:10. The reason was that the more dispersant was added to Bunker-C oil, the more were the oil droplets dispersed into seawater by dispersant, the more were the surface areas of oil droplets increased and the easier were the oil droplets degraded by microorganisms(Canevari, 1969; Tarzwell, 1969; Brown, 1987).

5. Deoxygenation rate(K_1) and ultimate oxygen demand(L_0)

In order to obtain the deoxygenation rates and ultimate oxygen demands of dispersant(SG) and dispersant/Bunker-C oil mixtures(BC+SG), based on the BOD values with time, the regression lines for Thomas slope method were given in Fig. 3 and the results were presented in Table 8.

While the deoxygenation rate and ultimate oxygen demand for 4mg-SG/l of dispersant(SG) were 0.171/day and 3.810mg/l, respectively, the deoxygenation rates for mixtures(SG+BC) with mix ratios of 1:10~5:10 were 0.072~0.097/day and no significant differences were found among various mixtures with different mix ratios. However, the ultimate oxygen demands for mixtures(SG+BC) were in the range of 1.113~6.746mg/l and were increased with mix ratios changing from 10:1 to 10:5. This means that the more dispersant is applied to Bunker-C oil spilled at sea, the more is dissolved

oxygen consumed in the seawater(Dewling *et al.*, 1971).

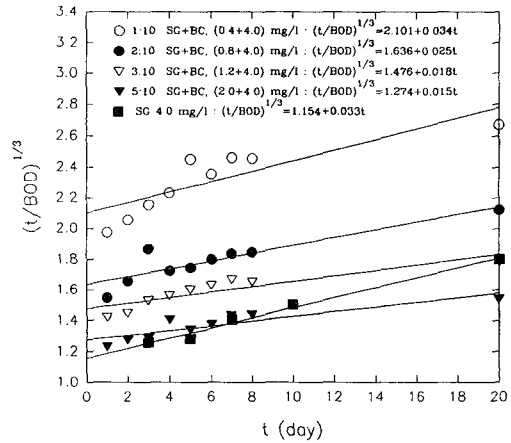


Fig. 3. Regression lines of dispersant(SG) and dispersant/Bunker-C oil(SG+BC) for Thomas slope method.

Summary and Conclusion

The biodegradation experiment, the TOD analysis and the element analysis for dispersant(SG), Bunker-C oil(BC) and dispersant/Bunker-C oil mixtures(SG+BC) were conducted for the purposes of evaluating the biodegradability of Bunker-C oil treated and mixed with dispersant and studying the consumption of dissolved oxygen with relation to biodegradation in the seawater.

1mg of Bunker-C oil was found to be equivalent to 3.16mg of TOD while 1mg of dispersant was

Table 8. Deoxygenation rates(K_1 , day⁻¹), ultimate oxygen demands(L_0 , mg/l), correlation coefficient(r), intercept (a) and regression coefficient(b) of dispersant(SG) and mixtures(SG+BC)

	Dispersant		Mixtures		
	SG (4.0) mg/l	1:10 SG+BC (0.4+4.0) mg/l	2:10 SG+BC (0.8+4.0) mg/l	3:10 SG+BC (1.2+4.0) mg/l	5:10 SG+BC (2.0+4.0) mg/l
K_1	0.171	0.097	0.093	0.073	0.072
L_0	3.810	1.113	2.447	4.261	6.746
r	0.994	0.854	0.898	0.892	0.883
a	1.154	2.101	1.636	1.476	1.274
b	0.033	0.034	0.025	0.018	0.015

equivalent to 2.80mg of TOD.

The contents of carbon and hydrogen were 87.3 % and 11.5% for Bunker-C oil, and 76.5% and 12.2% for dispersant, respectively. The element of nitrogen was not detected in dispersant or Bunker-C oil.

For (0.4mg-SG+4.0mg-BC)/l, (0.8mg-SG+4.0mg-BC)/l, (1.2mg-SG+4.0mg-BC)/l and (2.0mg-SG+4.0mg-BC)/l of dispersant/Bunker-C oil mixtures in natural seawater, (1) the BOD₅ and BOD₂₀ were found to be 0.34~2.06mg/l and 1.05~5.47mg/l, respectively, and the BOD value was increased as the mix ratio of dispersant to Bunker-C oil changed from 1:10 to 5:10. (2) the biodegradability was found to be in the range of 3~11% and this means that the mixtures with mix ratios of 1:10~5:10 belong in the organic matter group of low-biodegradability. The biodegradability was also found to increase from 3% to 11% as the mix ratio of dispersant to Bunker-C oil changed from 1:10 to 5:10. (3) the deoxygenation rate was found to be in the range of 0.072~0.097/day, and the ultimate oxygen demand was also found to increase from 1.113 mg/l to 6.746mg/l as the mix ratio of dispersant to Bunker-C oil changed from 10:1 to 10:5.

References

- APHA-AWWA-WPCF. 1989. Standard methods for the examination of water and wastewater. 17th Ed. Washington. USA. 5-2~5-10.
- Brown, L. R. 1987. Oil-degrading microorganisms. Chemical engineering progress, 35~40.
- Canevari, G. P. 1969. General dispersant theory. Proceedings of joint conference on prevention and control of oil spills, API/FWCPA, USA., 171~177.
- Dewling, R. T., J. S. Dorrlor and G. D. Pence. 1971. Dispersant use vs water quality. Proceedings of joint conference on prevention and control of oil spills, API/EPA/USCG, USA., 271~277.
- Gatellier, C. R., J. L. Oudin, P. Fusey, J. C. Lacaze and M. L. Priou. 1973. Experimental ecosystems to measure fate of oil spills dispersed by surface active products. Proceedings of joint conference on prevention and control of oil spills, API/EPA/USCG, USA., 497~504.
- Inoue, J. 1972. The chemical structures and biodegradability of various organic matters. Journal of water and waste. 14(12), 142~166.
- Institute of petroleum. 1986. Guidelines on the use of oil spills dispersants, 2nd Ed., 14pp.
- Kahng, S. H., J. R. Oh and D. B. Yang. 1991. Laboratory simulation of formation, prevention and breaking of water-in-oil emulsion. J. Oceanol. Soc. Korea. 26(4), 324~331.
- Kim, D. K., Y. S. Suh, J. S. Song, M. H. Lee, S. Y. Yang, J. D. Choi, J. J. Kim, B. H. Ahn and S. J. Kim. 1987. Genetic engineering in environmental research—Isolation of oil degrading microorganisms—. Report of NIER, Korea, 9, 127~132.
- Kim, S. J. and C. K. Park. 1982. A study on the correlation among BOD, COD, TOD and TOC values for fooding-processing wastewaters. J. of Kor. Soc. Env. Eng. 4(1), 8~21.
- Korean Industrial Standards. 1984. KSM-2800.
- Korea Maritime and Port Authority. 1979. Notice of KMPA-No. 217.
- Lee, H. W., N. Kobayashi and C. R. Ryu. 1990. Review on oil spills and their effects. Research report, No. CACR-90-03, Center for applied coastal research development of civil engineering, University of Delaware, Newark Delaware, USA., 89pp.
- Lee, Y. and S. J. Kim. 1985. Potentiality of bacterial degradation of oil in coastal water. J. Kor. Wat. Pollut. Res. Contr. 1(1), 1~8.
- National Maritime Police ROK. 1987. A study on the composition change of oil spill dispersant. Experimental & Research Report, 3, 92~116.
- National Maritime Police ROK. 1990. A study on the treatment of oil spill by oil degrading microorganisms. Experimental & Research Report, 5, 25~40.
- Okasawa, W. 1970. The biodegradability of various organic matters, a collection of research papers of the 6th forum for the study of sanitary engineering, Japan. 1.
- Society for the study of Surfactant. 1986. The elucidation of the function of newly-developed

- surfactant and the development of its applied products. Management development center pub. Co. Osaka, Japan. 489~496, 980~997.
- Society for the study of Tanker oil pollution. 1976. The countermeasure and control of oil spill accidents. Nariyamado pub. Co. Tokyo, Japan. 143pp.
- Takemoto, S., E. Mitani, C. Matsushita, S. Tabuki, Y. Kuge and S. Asado. 1978. Study of BOD test for industrial wastes containing sea water. Journal of Environmental Pollution Control, 14 (9), 77~85.
- Thomas, H. A. 1950. Graphical determination of BOD curve constants. Water and Sewage Works, 97, 123pp.
- ZoBell, C. E. 1969. Microbial modification of crude oil in the sea. Proceedings of joint conference on prevention and control of oil spills, API/FWCPA, USA., 317~326.

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海水中에서 油處理劑 및 油處理劑/Bunker-C油 混合物의 生分解度와 溶存酸素消費에 관한 研究(II)

— 유처리제/Bunker-C유 혼합물의 생분해도와 용존산소소비 —

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해수중에서 유처리제에 의해 유화·분산된 Bunker-C유의 생분해도와 이로 인해 나타나는 용존산소소비를 연구할 목적으로 국내에서 시판 중인 유처리제 및 국내 연안에 있어 유류오염사고의 주종을 이루고 있는 Bunker-C유에 대한 TOD분석과 원소분석을 행하고, 또한 Bunker-C유/유처리제 혼합물에 대해 천연해수를 이용한 생분해 실험을 행한 결과를 요약하면 다음과 같다.

1. 1mg의 Bunker-C유는 3.16mg의 TOD를 나타내는 반면에 1mg의 유처리제는 2.80mg의 TOD값을 나타내었다.
2. Bunker-C유는 87.3%의 탄소와 11.5%의 수소를 함유하였으며, 유처리제는 76.5%의 탄소와 12.2%의 수소를 함유하였다. Bunker-C유와 유처리제 중 어느 시료에서도 질소는 검출되지 않았다.
3. 천연해수 중에서 일정량의 Bunker-C유(4mg/l)에 대하여 유처리제를 10:1~10:5의 혼합비율로 첨가한 Bunker-C유/유처리제 혼합물에 관해서 정리하면, 혼합물의 BOD₅는 0.34~2.06mg/l였고 BOD₂₀는 1.05~5.47mg/l였다. 또한 혼합비율이 증가함에 따라 혼합물의 BOD는 증가하였다.

혼합물은 생분해도(BOD₅/TOD)가 3~11%로서 저속 분해군에 속하였다. 또한 혼합비율이 10:1에서 10:5로 증가함에 따라 혼합물의 생분해도는 3%에서 11%로 증가하였다.

혼합물의 탈산소계수(K₁)는 0.072~0.097/day였으며, 혼합물의 최종산소요구량(L₀)은 1.113mg/l~6.746mg/l로서 혼합비율이 증가함에 따라 최종산소요구량도 증가하였다.