# DEVELOPMENT OF A WATER-QUALITY MONITORING TECHNIQUE DURING DREDGING OF DIOXIN-POLLUTED SEDIMENTS

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**Introduction**

Japan mandates the environmental standard for dioxin concentration of 1 pg-TEQ/L in the regulations concerning water pollution (Environment Agency Announcement No.68, December 27, 1999) and 150 pg-TEQ/g in the regulations concerning sediments (Environment Agency Announcement No.46, July 22, 2002). Dredging is under way in some sea areas around the nation in accordance with these requirements. Dredging is considered to be highly effective in reducing risks posed to humans when they eat fish caught in the sea area as dioxin-polluted sediments are removed from the sea floor under this technique. During dredging, however, this method may pose secondary pollution risks that may be caused by floating and diffusion of polluted sediment particles. For this reason, efforts are being made to develop technologies for efficient dredging without pollution dispersion, for preventing water turbidity, or for monitoring water quality. This paper presents the results of a field study on water-quality monitoring technology as part of the authors' development activities for sediment processing technology.

**Materials and Methods**

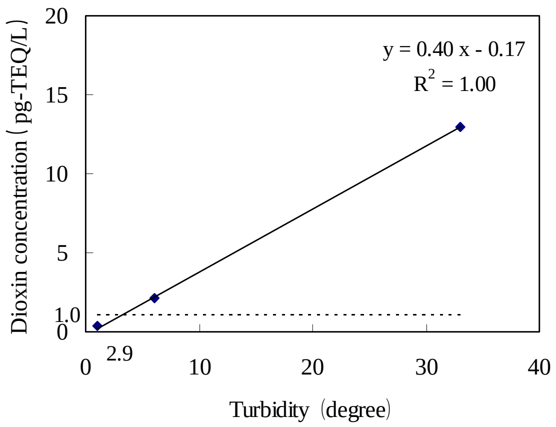
1. Concepts and problems concerning water-quality monitoring during dredging

Figure 1 shows the position of water-quality monitoring points specified in Japan ' s guidelines for dredging of dioxin-polluted sediments[1]. These guidelines prescribe the water area (ordinary water area) that should be free from the effects of dredging operation and the water area to be involved in dredging operation (dredging-related water area). Environmental monitoring needs to be conducted at main observation points on the borderline between the ordinary water area and the dredging-related water area. The dredging results must meet the water-quality standard of 1 pg-TEQ/L at these points. Anti-turbidity measures may include the installation of a turbidity control membrane around dredging sites. Meanwhile, one way of monitoring is to measure the dioxin concentration in water in accordance with an established law. This monitoring method, however, is not applicable when monitoring results need to be acquired promptly to implement necessary measures because this method takes about one month to produce such results. Thus, expectations are high for development of a new technique that can produce monitoring results at an early date and reflect them in dredging operation.

2. Water-quality monitoring technique based on turbidity

Under the current available technology, turbidity measurement provides a convenient way of obtaining monitoring results in a prompt manner. With this technique, taking advantage of the fact that dioxins are scarcely soluble in water and instead adsorb onto soil particles, a preliminary field survey is conducted on a correlation between the turbidity and the presence of dioxins in the target water area in order to establish a reference turbidity value. Figure 2 shows as an example a survey conducted in Tokyo Bay. In this case, the turbidity corresponding to 1 pg-TEQ/L was 2.9 with a relation of $y = 0.40x - 0.17$ (y: dioxin concentration pg-TEQ/L, x: turbidity). Assuming that the turbidity did not increase due to any other causes than dredging, the allowable monitored turbidity of the main observation points should be 2.9.

Conventionally, turbidity observation is performed by engineers as they visit observation points on a boat a number of times a day to make measurements with a turbidimeter. With highly dioxin-polluted sediments, however, even the generation of slight turbidity may worsen the water quality. It would therefore be extremely difficult to control the turbidity during dredging operation if measurement is made only a few times a day. To solve this problem, we developed a real-time turbidity monitoring system that can permit constant measurement to promptly reflect its results on dredging operation.



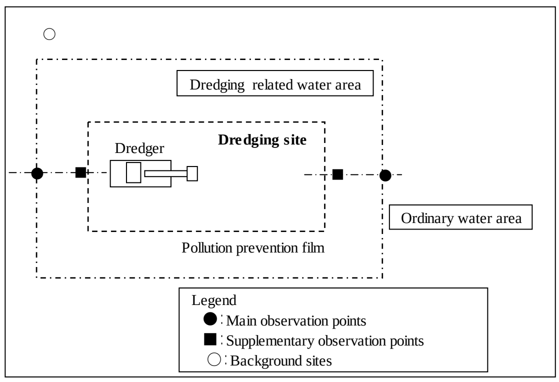




Fig.1 Main observation points for monitoring dioxins during sediment dredging.

Fig.2 Example of relationsh1ip between turbidity and dioxin concentration

3. Monitoring by DR-CALUX

The authors conducted water-quality monitoring using DR-CALUX (Dioxin Responsive Chemical Activated LUciferase eXperession, an Ah receptor-reporter gene assay using a rat hepatoma H4IIE-luc cell)[2]. This technique is thought to provide more accurate results than turbidity measurement and produce dioxin analysis results in only a few days. The technique was applied to anti-pollution dredging of sediments. In our experiment, water samples were taken from main observation points and auxiliary monitoring points, and for reference, from some dredging sites. The water samples were concentrated after solvent extraction and treated with a sulfuric acid silica gel column. TEQ measurement was performed on the samples using DR-CALUX. The conditions for cell culture and the procedure of the DR-CALUX assay have been described in detail elsewhere[3]

**Results and Discussion**

1. Development real-time turbidity monitoring system[4]

Figure 3 shows ocean observation equipment as part of our real-time turbidity monitoring system. This equipment is composed of a power supply and a data communication device installed on a float, and a sensor and other devices suspended under water (turbidimeter and wind current direction velocity meter), in addition to mooring instruments. Under this system, the ocean observation equipment constantly measures the turbidity, current direction and current velocity and transfers the data in real time to a central control system over a wireless LAN. The measurement data can be used as feedback to the dredging site. For example, if this system is installed at a main observation point, the operator of the dredging boat can engage in dredging operations while constantly watching the reference monitoring value and the turbidity displayed on the screen as shown in Figure 4. Thus, the operator can quickly take necessary actions when the turbidity approaches the reference value.

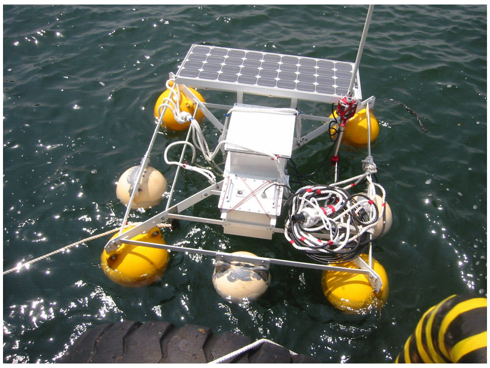


Fig.3 Marine observation device

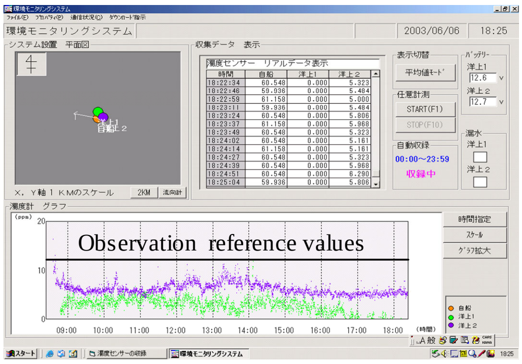



Fig.4 Monitor screen

2. Water-quality monitoring based on DR-CALUX

Table 1 shows the results of analysis of water samples collected during dredging operation from dredging sites, main observation points, and background points. The estimate A of WHO-TEQ provided in the table was calculated using formula y=0.56x (y: WHO-TEQ estimate pg-TEQ/L, x: CALUX-TEQ pg-TEQ/L) obtained from past common cases of public waters and CALUX-TEQ values analyzed during the dredging operation. These analytic results showed that the turbidity at main observation points were in compliance with the water-quality standard of 1 pg-TEQ/L, indicating that dredging was being performed without any environmental problems. After completion of the dredging operations, analysis confirmed that the value B of WHO-TEQ obtained using the HRGC/HRMS method complied with the same environmental standard.

Table.1 Analytical results of environmental water samples (CALUX-TEQ and WHO-TEQ)

| | Monitoring Point | CALUX-TEQ (pg-TEQ/L) | Predicated WHO-TEQ：A *) (pg-TEQ/L) | WHO-TEQ：B (pg-TEQ/L) | Ratio (A/B) |
|---|---|---|---|---|---|
| Sample set 1 | Dredging site | 4.9 | 2.7 | 2.8 | 0.98 |
| | Main observation point | 0.5 | 0.28＜1.0 | 0.12＜1.0 | 2.33 |
| | Background site | 1.2 | 0.67 | 0.14 | 4.80 |
| Sample set 2 | Dredging site | 1.7 | 0.95 | 0.33 | 2.88 |
| | Main observation point | 0.99 | 0.55＜1.0 | 0.20＜1.0 | 2.77 |
| | Background site | 1.2 | 0.67 | 0.28 | 2.40 |

*)Predicted WHO-TEQ values were obtained from CALUX-TEQ by conversion factor specific to the site.

3. Conclusion

The real-time turbidity monitoring system developed by us was designed to permit turbidity measurement in real-time and constantly reflect the measurement results on dredging operations.

Generally, problems with turbidity measurement include the assurance of accuracy in determining the correlations between turbidity and dioxin concentrations and a potential increase in measured turbidity at dredging sites due to an additional increase in turbidity around these dredging sites generated by several factors (e.g., swirling of sediments caused by passing vessels and inflow of suspended solids from rivers).

DR-CALUX was successfully applied to site management as a monitoring technique that can produce high-accuracy analytic results in only three days to reflect them in dredging operations in a timely manner.

**References**


1. Ports and Harbors Bureau, Ministry of Land, infrastructure and Transport, Japan：Technical Guidelines for Countermeasure to Dioxins in Port and Harbor Bed Material(Revised), 5-9(2003) (in Japanese)
2. Behnisch, P.A., Hosoe, K., Sakai, S.: Combinatorial bio/chemical analysis of dioxin and dioxin-like compounds in waste recycling, feed/food, humans/wildlife and the environment, Environment International, 27,495-519(2001)
3. Takigami, H., Sakai, S., Brouwer A.: EnvironTechnol; 26, 459-469(2005)
4. Sato, M., Kurumada, Y., Moriya, Uehara, T., Takigami, H.,Sakai, S.: Field survey on turbidity during environmental dredging and proposal of new monitoring technique, Annual Journal of Civil Engineering in the ocean, JSCE, 20,1127-1132(2004) (in Japanese)