A Biosensor for Detection of PCBs in Transformer Oil

Background

The use of polychlorinated biphenyls in transformer oil was discontinued in the late 1970's due to its toxicity. Currently, in the developed countries, the degradation programs for PCB contaminants are operated with environmental monitoring. Several methods including an extraction followed by gas chromatography (GC) with electron capture or mass spectrum (MS) were used to monitor PCB in oil, but more rapid and cheaper methods are coming to be focused and desired. Immunoassay using antibody and antigen reaction is expected to be a rapid and cheap detection method for PCB in oil. However, the multiple detection of PCB congeners and/or the disruption of antibody reaction by the oil content are thought to be difficult problems facing immunoassay for PCB in oil. A little information is available for effective immunoassay with simple extraction.

Objectives

Development of a simple and rapid immunoassay to detect PCB in transformer oil.

Principal Results.

1. A simple extraction method of PCB in oil.

To evaluate immunoassay for PCB in oil, a simple extraction method to extract PCB from oil is necessary. In extraction process, the oil contents preventing antibody reaction must be removed as rapidly and simply as possible. A liquid extraction by HCl-DMSO(dimethyl sulfoxide) followed by secondary liquid extraction by DMSO could extract PCB from oil. This less complicated 2 step liquid-liquid extraction was suitable for the developed immunoassay (Fig-1). 50% of PCB in oil could be recovered as the extract with this method.

2. Measurement of the imitated oil by spiking kanechlor

Four kinds of Kanechlor (KC300 - 600) are a mixture of PCB congeners. Thus, the contaminated oil was imitated by spiking each Kanechlor to PCB free transformer oil. The spiked PCB to the oil was extracted by the method described above. The extract was diluted 1000 fold with the solution containing anti-PCB antibody. The diluted mixture was subjected to PCB detection with our biosensor(FIg-1). PCB congeners could be detected at ppb level within 5 minutes on the sensor.(Fig-2)。 The final dynamic range of total PCB congeners in the oil was calculated from the dilution factor as 10 - 1400ppm for KC300, 6 - 600ppm for KC400, 2 - 100ppm for KC500 and 2 - 100ppm for KC600.

3. Measurement of the real contaminated oil from transformer

Total concentrations of PCB in 11 of real contaminated oils from the transformer (0.3~32ppm) were measured with a high resolution mass spectrum (GC-HRMS) and this biosensor. A high correlation was observed between output signals from the biosensor and the determined PCB concentrations by GC-HRMS (Fig -3). From this correlation, the dynamic range of total PCB congeners in oil on the biosensor was calculated as the range from 5 to 120ppm. A simple two steps liquid-liquid extraction in conjunction with an immunoassay for detecting PCBs in transformer oil was successfully achieved.

Future Developments

We will improve the sensitivity of biosensor with the extraction method.

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Reference

Naoya Ohmura. Application of biological function to sensing part 5 (in Japanese). CRIEPI report:U02032 (2004)

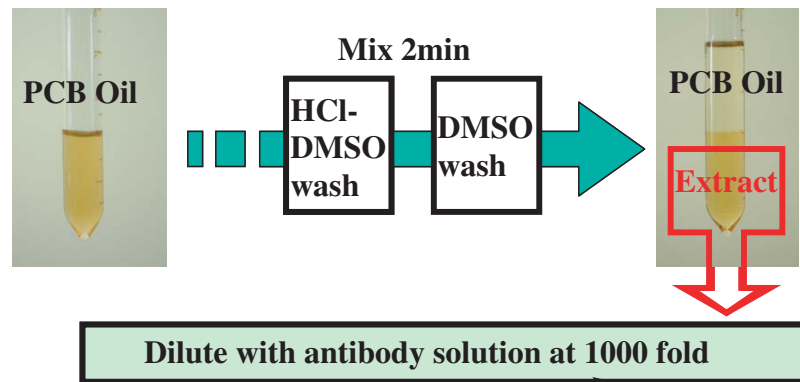**Dilute with antibody solution at 1000 fold**

Fig.1 The extraction and measurement
The PCB congener was extracted from oil by HCl-DMSO followed by neutral DMSO. The extract was diluted at 1000 fold with the anti-PCB antibody solution and the mixture was subjected to the biosensor to detect PCB. In the absence of PCB in the extract, the resultant signal on the biosensor was large. In the presence of PCB, the signal was appeared to be small.
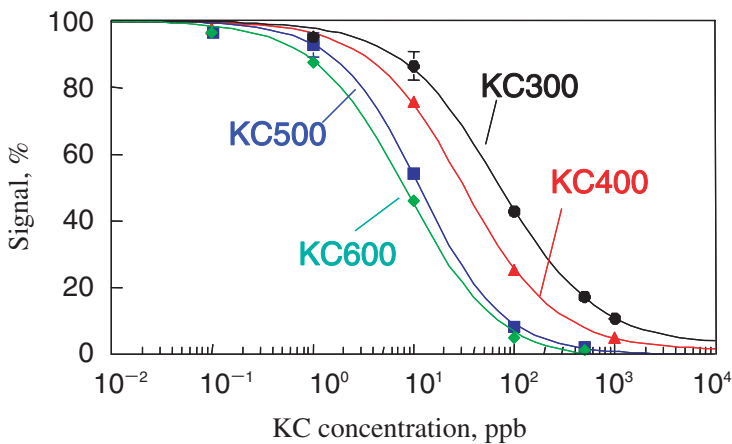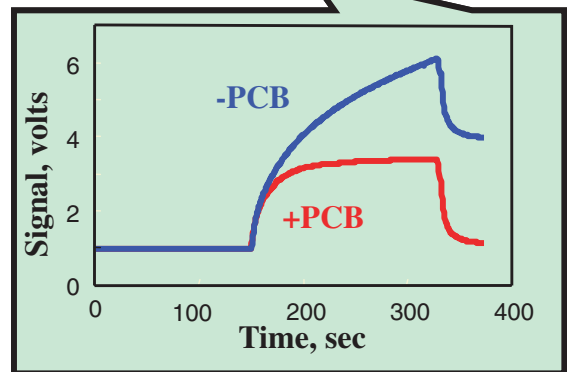

Fig.2 PCB measurement in the imitated oil. Four kinds of KC (300~600) were spiked to PCB free oil. The spiked concentrations of PCB in each KC could be determined from the signal.
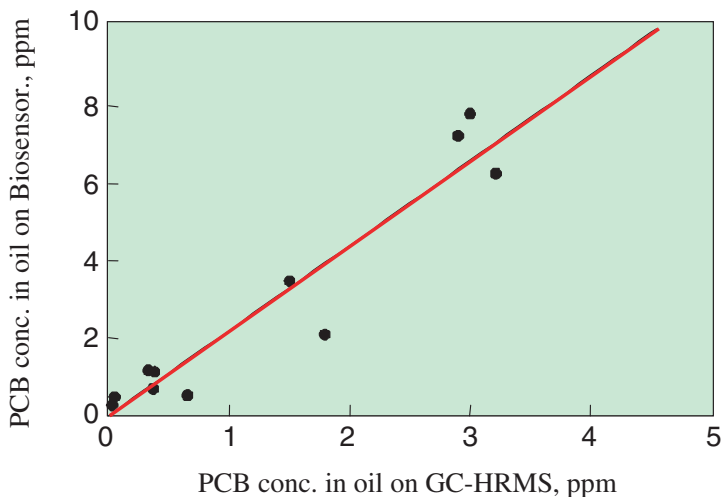

Fig.3 The relationship in total PCB concentrations in real transformer oils between biosensor and GC-HRMS. The relation coefficient was 0.96.