Development of a practical working model of an antibody-based PCB biosensor

Background

Contamination of transformer insulating oils by PCBs (polychlorinated biphenyls) was reported in 2003. Identification of contaminated transformers requires PCB analysis but previous methods were time consuming, expensive, and required highly skilled operators. In order to provide a rapid and cheap PCB analysis, we investigated a PCB biosensor using antigen-antibody reaction. The development of a practical model of the PCB biosensor is urgently needed to identify contamination in a large number of transformers.

Objectives

The purpose of this study is to develop a practical antibody-based PCB biosensor model and verify its usefulness as a rapid screening tool for contamination.

Principal Results

1. Preparation of PCB antibody

A mouse monoclonal anti-PCB antibody was successfully prepared. The antibody binds to four types of Kanechlor (A Japanese commercial mixture of PCB congeners), with minimal differences in binding affinities among the four types. The similar binding affinity enables detection of total PCBs present without regard to which congeners are present. The high average affinity enables highly sensitive determination of PCBs (Fig 1).

2. Practical model of PCB biosensor

A practical protocol for rapid measurement using the antibody with a specially developed portable instrument was established (Fig 2). The dynamic range was from 0.1mg-PCB/kg-oil to 2.0mg-PCB/kg-oil in insulating oil containing mixed PCBs with equal quantity of four types of Kanechlor. Eighty samples could be measured in a day due to parallel operation of assay.

3. Prediction and verification of screening by PCB biosensor

A new procedure to predict false positive ＊1 and false negative ＊1 rates was proposed and developed. The procedure relies on known or estimated sample distributions in conjunction with the standard deviation of the biosensor results and the slope and intercept of the biosensor calibration curve. In a verification test using 110 used transformer oils, the predicted proportion of false negatives and false positives agreed well with the measurements. The results provide strong evidence for the utility of the PCB biosensor and exhibited the usefulness of the prediction procedure (Fig 3).

The developed PCB biosensor has been commercialized and is now in routine use for screening transformer oil.

Future Developments

A modification of PCB biosensor to measure less than 0.1mg-PCB/kg-oil.

Main Researcher: Naoya Ohmura, Ph. D.,
Senior Research Scientist, Biotechnology Sector, System Engineering Research Laboratory

Reference

N. Ohmura, et al., 2009, “ Application of biological function to sensing part 7 ”, CRIEPI Report V08053 (in Japanese)

＊1：False Positive rate: The proportion of non-contaminated samples measured as contaminated by the screening method.
False Negative rate: The proportion of contaminated samples measured as non-contaminated by the screening method.

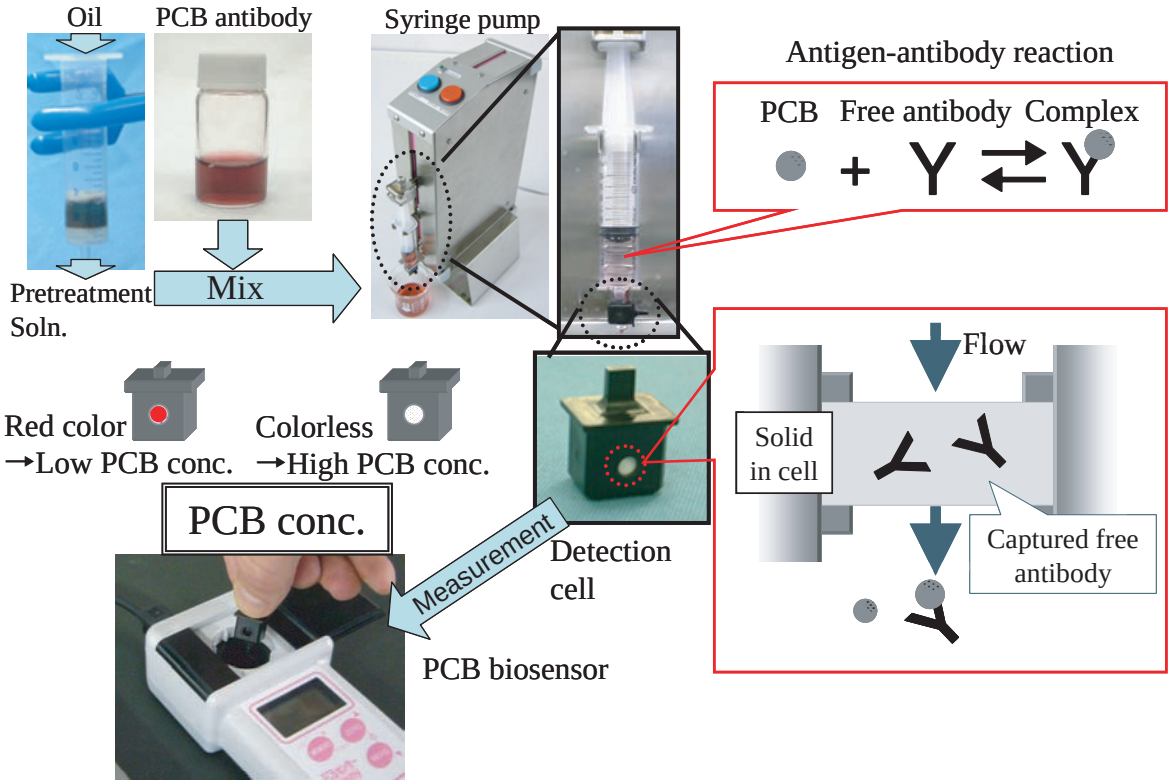

Fig.2 Measurement procedure of PCB biosensor

The sample after pretreatment was mixed with antibody for antigen-antibody reaction and the mixture was flowed through the detection cell by syringe pump. The free antibody concentration directly relates with PCB concentration in the mixture. Binding of the colloidal gold labeled antibody in the detection cell is inhibited by PCBs present in the sample.

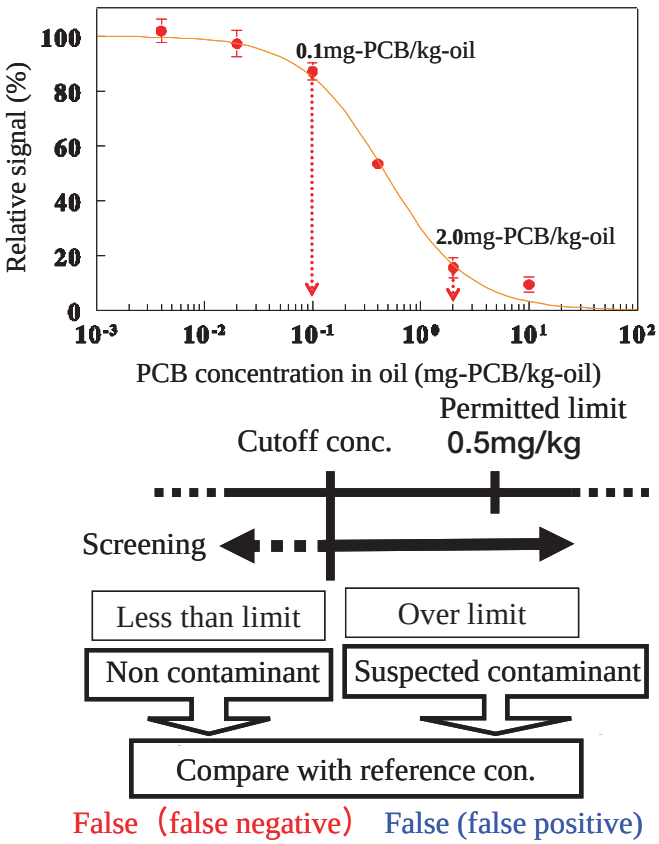

Fig.1 Dynamic range of PCB concentration in oil (Left).

Fig.3 Verification and prediction of screening (Lower)

110 oils from transformer were screened by biosensor at various cutoff concentrations. The proportion of false negatives and false positives was obtained from reference PCB concentrations determined by high resolution mass spectrometer. The false negative and false positive proportion well matched with the proportion predicted by the mathematical model.