

Demonstration of a Simplified Treatment Technique for PCB Contaminated Transformers

Background and Objective

In 2002, traces of polychlorinated biphenyls (PCBs) were confirmed to exist in electric equipment such as transformers. The establishment of rapid and cost-effective measurement techniques to check for PCB contamination and efficient and economical techniques for cleaning contaminated equipment has been required due to the numerous number of electric equipment that are suspected to be PCB contaminated.

The objective of this study is to improve the PCB measurement technique and develop techniques for cleaning transformers by (1) forcibly circulating a heated insulating oil and (2) spontaneously circulating a heated insulating oil by energizing them in order to remove PCBs, and ultimately reduce the cost of cleaning transformers contaminated with traces of PCBs.

Main results

1 Development of an improved PCB biosensor

The PCB biosensor using an antigen-antibody reaction that was previously developed by our laboratory was improved. We developed techniques to extract PCBs from insulating oil and measure the concentration of PCBs in the oil by constructing flow channels on a substrate with a microstructure (Fig. 1). Using this technique, the measurement time for the PCB biosensor is expected to be reduced to

approximately one-third (approximately 40 min) and the amount of required reagents to approximately one-tenth. Regarding the insulating oil collected from the transformers, the PCB concentration measured by our method is in good agreement with that measured by the official method,* demonstrating the high precision of our method (Fig. 2) (V12005).

2 Onsite demonstration tests to clean PCB-contaminated large transformers

Cleaning techniques involving heating and forced circulation and spontaneous circulation by energizing are being developed at our laboratory for investigating PCB-contaminated transformers. Using these techniques, ten regional electric power companies, J-POWER, and the Japan Atomic Power Company jointly carried out onsite demonstration tests at sites where transformers are either stored or used. In the cleaning test involving heating and forced circulation at a site where transformers were stored, the temperature of the cleaning oil was decreased from the

conventional 70°C to 40°C to reduce the cost required for cleaning, and three large transformers were cleaned (Fig. 3). In the cleaning test involving spontaneous circulation by energizing, four large transformers connected to the source of a power system were cleaned daily for at least 90 days at their site of use. The results of each demonstration test satisfied the PCB criteria set by the Ministry of the Environment. The results were reported to the PCB Treatment Technology Council of the Ministry of the Environment.

3 Confirmation of PCB removal efficiency by analysis of PCB balance

To verify the PCB removal efficiency, we analyzed the PCB balance before and after cleaning in the onsite demonstration tests involving heating and forced circulation and spontaneous circulation by energizing in order to estimate the PCB removal efficiency. For the former method, 99.2 to 99.7% of the PCBs contained in the oil and structural members of the large transformers were removed by cleaning at 40°C, giving a PCB removal

efficiency comparable to that obtained at 70°C. Similarly, for the latter method, 99.3 to 99.7% of the PCBs contained in the large transformers were removed by cleaning. As explained, a PCB removal efficiency of at least 99%, which was our initial target, was achieved and most of the PCBs contained in the transformers were thus demonstrated to be removed by the two cleaning techniques (Table 1).

* The official method refers to the test method described in the standards regarding general waste subject to special control and industrial waste subject to special control (see Table 2, Analysis Method of PCBs in Oil, Ministry of Health, Labour and Welfare, Notification No. 192 of 1992).

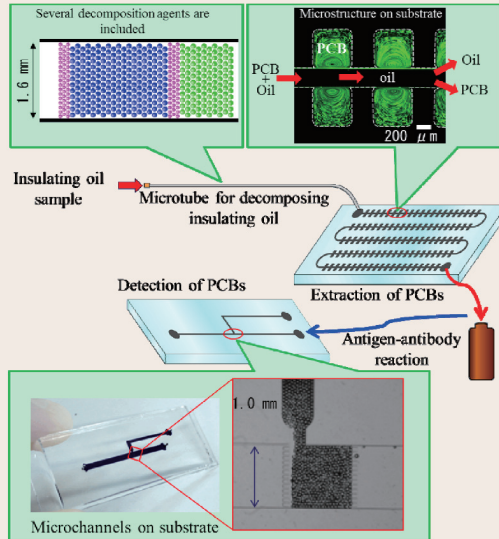


Fig. 1: PCB biosensor developed by microfabrication technology

PCBs are extracted from the insulating oil in the flow channels on the substrate with a microstructure via microtubes filled with an oil decomposition agent. The PCBs in the extracted oil are detected on the substrate with microchannels by an antigen-antibody reaction.

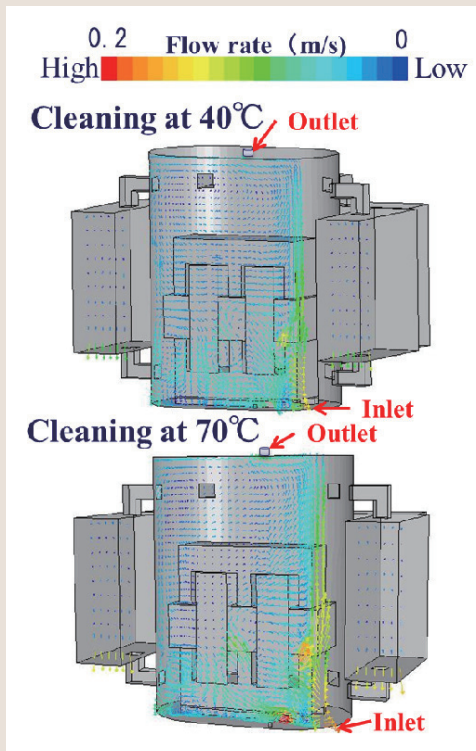


Fig. 3: Simulation of the flow of cleaning oil in a transformer during cleaning involving heating and forced circulation for cleaning oil temperatures of 40 and 70°C

It is assumed that the amount of oil in the transformer is approximately 14,000 L, the flow rate of the cleaning oil at the inlet is approximately 250 L/min, and that the oil is drained from the outlet and recirculated. The flow rate is almost the same regardless of the temperature. It was found that the cleaning oil circulates throughout the transformer even when the temperature is 40°C.

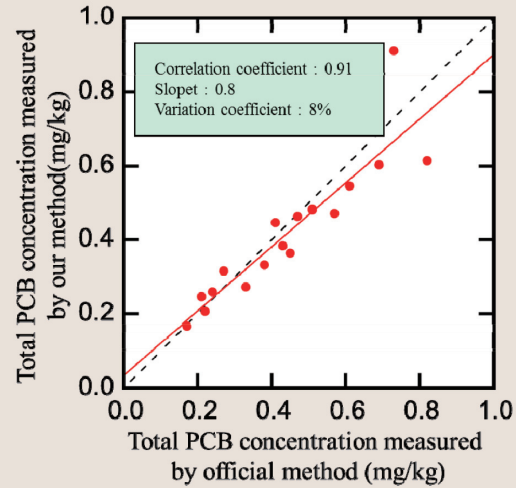


Fig. 2: Correlation between the result obtained using the biosensor developed by microfabrication technology and the result obtained by the official methods

The figure shows the correlation between the total PCB concentrations measured by our method and the official method for 18 samples of insulating oil collected from transformers. In the future, we aim to improve the accuracy so that our method can be approved as an official method.

Table 1: Results of evaluating PCB removal efficiency by balance analysis

The amount of PCBs attached to the container of the transformer (per area) and the amount contained in the structural members (per weight) were measured to analyze the PCB concentration before and after cleaning using the surface area of the container and the weight of the structural members. The rates of PCBs removed by cleaning were compared with respect to the total amount of PCBs before cleaning.

Cleaning technique	Test location	Cleaning conditions	Removal rate(%)
Heating	A	Forced circulation at 70°C	99.1
	B		98.9
	C	Forced circulation at 40°C	99.2
	D		99.6
	E		99.7
Energizing	F	Spontaneous circulation for at least 90 days	99.7
	G		99.7
	H		99.5
	I		99.3