

EFFICIENT METHODS FOR PCB REMOVAL FROM PCB-CONTAMINATED TRANSFORMERS BY CHANGE AND RECYCLE TRANSFORMER INSULATING OIL

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Abstract

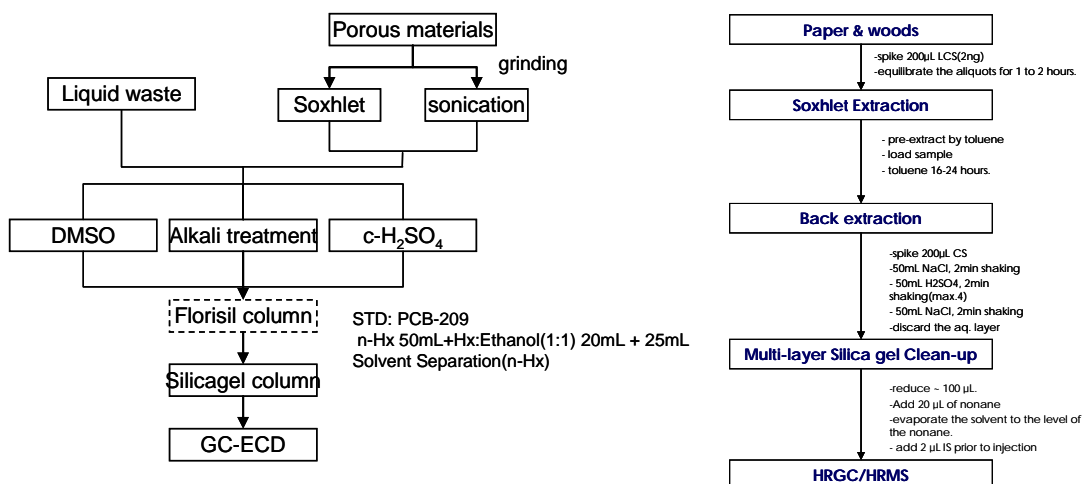
In order to possibly reuse PCB (Polychlorinated Biphenyls)-contaminated transformers, effective retrofiling methods for complete PCB removal should be developed. Because original material of new transformer and treated material of PCB-contaminated transformers have a very low concentration of PCB that cannot be detected by GC-ECD (detection limit of 0.05 $\mu\text{g/g}$), the total amount of PCB was obtained using HRGC-HRMS. Transformers contaminated with PCB levels above 20 ppm from the first analysis using PCB analysis kits (L2000) and METHOD 9079 (Clor-N-Oil) were more accurately analyzed with GC- μECD . Transformers with 20 ppm PCB-contaminated oils had parts containing PCBs ranging from 0.05 to 3.8 $\mu\text{g/g}$. PCB concentrations analyzed from metal parts were lower than PCBs analyzed from porous parts. PCB concentrations of the porous parts were above 2 ppm (Korea's limited concentration standard) and PCBs were not completely removed by a single change with new oils. Approximately 91% of PCBs were removed from transformers with PCB levels below 50 ppm by replacing oils with new transformer oils. The PCB removal efficiency from the transformers with PCB levels from 50 to 500 ppm was approximately 95 % after the second oil washing but increased up to 99% by high temperature oil circulation. Adding solvent washing to oil changes greatly improved the PCB removal efficiency.

Introduction

As a party to Stockholm Convention, the Korean government decided to completely eliminate PCBs (polychlorinated biphenyls) including PCBs in transformers, capacitors or oils by 2015.¹ Contaminated transformers and capacitors with PCB can be reused after removing PCBs by removing contaminated oils and washing or retrofilling with new insulation oils or organic solvents.² Because transformers and capacitors are composed with several different materials and PCB concentrations of contaminated equipments vary significantly, complete removal of PCBs by washing or retrofilling cannot be easily achieved. Under the Korean EPA regulations, PCB-contaminated transformers with PCB levels below 2 ppm are considered non-PCBs. By comparing PCB removal from highly contaminated transformers with lowly contaminated transformers, both effective and economical methods were presented as a future guideline for the treatment and management of PCB-contaminated transformers and capacitors.

Materials and Methods

Three hundred PCB-contaminated transformers were collected in Korea. A standard procedure was used to determine the congeners and total PCBs (GC-ECD, L2000, HRGC-HRMS). PCBs absorbed in the core materials of transformers were extracted using soxhlet extraction and by sonication. Extracts after cleaning-up with H₂SO₄, Florisil, and silica-gel were analyzed with GC (gas chromatography) with electron capture detector. Prior to accurate analysis using GC-ECD or HRMS-HRMS, rough quantification was carried out by L2000 kits which use chloride-selective electrodes. Scheme of analytical procedure by HRGC-HRMS is shown below.



Results and Discussion

The PCBs concentration of initial insulating paper and press board was 0.16 ng/g and 0.13ng/g, respectively. Therefore there was no transfer of PCBs from insulating materials to oil.

Washing contaminated transformers was carried out by changing oils with new insulation oils or circulating 70°C oils for hours. Table 1 shows a brief description of our methods used for the experiments. The PCB concentrations analyzed from the transformer parts we tested are shown in Table 2.

Table 1 Experimental conditions and analytical methods for PCB removal from transformers with different concentrations of PCBs

PCBs Conc. (ppm)	≤2 - <50	≤50 - < 500	≥ 500
Cleaning Method	cold transformer oil 10% 2x	100% 1x overnight	hot oil 150% 70°C 15hr Circulation
Analytical Method	GC-ECD HRGC/HRMS	GC-ECD HRGC/HRMS	L2000 HRGC/HRMS
Time of analysis	Initial, 1 st Cleaning, 2 nd Cleaning, Final	Initial, 1 st Cleaning, 2 nd Cleaning, Final	Initial, after every cycle (1cycle/30min), 2 nd Cleaning Final

Analysis after operation	Liquid analysis every week	Liquid analysis every week	Liquid analysis every week
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Table 2. PCB concentration of transformer parts

	<i>Insulation Oil Conc. (ppm)</i>	<i>Sludge Conc. (µg/g)</i>	<i>Insulation Paper con. (µg/g)</i>	<i>Transformer and Aroclor Type</i>
Transformer 1	2.83	-	0.92	700KVA(1982) 1242:1254:1260(2:9:3)
Transformer 2	74.1	17.6	-	2000KVA(1974) 1254
Transformer 3	20.7	33.5	3.8	50KVA(1979) 1242:1254:1260(1:4:1)

Fig 1 shows the relationship between PCBs recovered from the cleaning oil and the number of cleaning circulation times. PCB concentrations were calculated from cleaning oils by both using analysis kits (L2000) and GC-ECD. There was a difference in PCB amount from the methods but the results showed a good correlation between the methods and PCB recovery ratios.

For transformers with PCB levels below 50 ppm did not have residual PCBs after cleaning with new oils twice. It was possible to reduce PCBs significantly from transformer with PCB levels of 50 to 500 ppm using hot oils changes (70 degrees for 15 hours). The analytical results from the cleaning experiments are shown in Table3. PCBs were removed from transformers with PCB levels below 50 ppm by a single trial of changing with new transformer oils (91%). The PCBs were almost completely removed by next oil change. The PCB removal efficiency from the transformers with PCB levels from 50 to 500 ppm was approximately 95 % after the second oil washing but increased up to 99% by high temperature oil circulation.

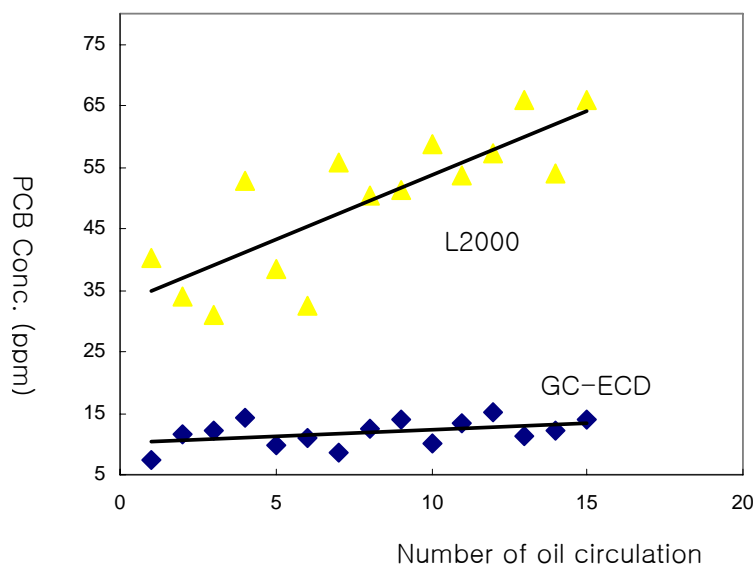


Fig. 1. Correlation of PCB and the number of oil circulation.

Table 3. PCB removal ratios after using cleaning oil

PCBs Conc. (ppm)	$\leq 2 - < 50$	$\leq 50 - < 500$	≥ 500
Total Amount of PCB (g)	15.2	20.7	201.7
Original Oil Drain (%)	85.2	84.9	85
100% New Oil x1 (%)	90.6	77	98.6
100% New Oil x2 (%)	99.9	94.9	99.8
100% New Oil x3 (%)		99.9	

We also recommend refilling with hot oils to remove PCBs from the transformers contaminated with a high level of PCBs (above 500 ppm). New methods for more efficient removal of PCBs from transformers including hot water jet cleaning and sonication were under investigation.

Acknowledgements

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References

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