CASE STUDY OF APPLICATION OF RISK ASSESSMENT FOR PCBs IN SOIL IN THE VICINITY OF TRANSFORMER RECYCLING PLANT

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Introduction

Polychlorinated biphenyls(PCBs) which are mainly used as insulating oil of electronic voltage transformer are persistent organic pollutants and endocrine disrupters. PCBs had variety of industrial used because of their heat stability, low reactivity and lubricating properties. Soil contamination is a concern in the regeneration process of the insulating oil contained PCBs. In the United States, the major emission sources of PCBs to the soil were found that landfill and ground storage facility are majority.

PCBs had not been manufactured in Korea and all of used PCBs at a long time ago were imported. Manufacturing, using and importing of PCBs were completely prohibited at 1996 by environmental law which is toxic chemicals control act of Korea. However, recycling of insulating oil containing PCBs that was used in previous regulation or flowing out in the transformer during storage is one of the pathways of soil contamination.

In this study, we examined the PCBs pollution level in the soil within the vicinity of insulating oil recycling facility. And the RBCA tool kit for chemical release which is environmental modeling and risk assessment software is used for the exposure level and evaluation of application of risk assessment.

Materials and methods

Site selection and soil sampling
Preliminary survey was conducted to select potentially high contaminated sampling site. Insulating oil production plant, transformer recycling plant and substation were investigated in advance. Transformer recycling plant was detected PCBs and this site was selected for this study.

The soil was sampled from the impacted workplace of transformer recycling plant. Eight points were sampled with five depth intervals (20 sampling in total). Sampling depths were 0~15 cm for topsoil, and, for subsurface soil, 15~30 cm, 30~50 cm, 50~70 cm and 70~90 cm. There were carried out determination of soil texture through using pipette method and determined using USDA texture triangle and organic matter content was measured through Walkley-Black method. Total PCBs were analyzed using Korean Persistent Organic Pollutant Public Testing Protocol. Extracts of samples are analyzed by gas chromatography with electron capture detection(GC/ECD). Aroclor category determined by the best match of peaks to aroclor reference standards.

Comparison & Selection of Risk Assessment Tool
Three widely used tools for assessment of risks to human health from contaminated land which are CLEA(contaminated land assessment model), CSOIL model and RBCA(Risk Based Corrective Action model) were compared and selected to RBCA Tool Kit for chemical release. The RBCA Tool Kit was developed by American Society for Testing and Materials(ASTM). This includes analytical fate and transport models for air, groundwater and soil exposure pathways, enabling evaluation of surface soil, subsurface soil, air, groundwater and surface water. However, contaminant concentrations can only be specified for soil and groundwater.

Results and discussion

Exposure pathway identification

The RBCA Tool Kit is widely divided into the term of "Tier 1" refers to a on-site receptor located at the source zone and term of "Tier 2" refers to a off-site receptor at any point away from the source zone. Tier 1 analyses involve generic risk-based screening levels for on-site exposure and Tier 2 analysis the user can evaluated baseline risk and site-specific target levels for both on-site and off-site receptors. In this study, the exposure pathways were considered with three sections: 1) groundwater exposure; 2) surface soil exposure; 3) air exposure.

On-site groundwater pathway was designated as ingestion of commercial receptors for Tier 1. Off-site groundwater pathway was designated as both ingestion of residential receptors and exposure to the discharge of surface water by affected soils leaching to groundwater for Tier 2. Receptor distances form source were 0.5km for the residential ingestion and 1.5km for the discharge of surface water, respectively. Surface water exposure pathway only involves human exposure via fish consumption. Surface soil exposure pathway to the commercial receptors was combined effects of dermal contact, incidental ingestion, inhalation of vapors and dust except for vegetable ingestion. Air exposure is only considered outdoor air inhalation of on-site commercial receptors and 0.5km distance residential receptors. Source media contributing to the outdoor air inhalation pathway was perceived as volatilization and particulates to ambient outdoor air.

Applicable exposure parameters were applied with ASTM standard E 2081 and Reasonable Maximum Exposure(RME) values specified in U.S. EPA guidance(U.S. EPA, 1997). Body weight and food consumption rate were just changed to fit the situation in South Korea. Body weight that is bivariate with man and woman was focused with woman. 60 kg of body weight of Korean woman. In contrast to the diet habit of the western, vegetable ingestion rate of Korean was about three times more than the meat ingestion rate and daily vegetable intake amount is about 1 kg. Vegetable ingestion and fish consumption rate were corresponded to Korea Statistical Yearbook of 2012. Representative source media constituent of concern concentration was calculated by geometric mean of twenty of soil samples. Value of upper confidence limit(UCL=mean+standard deviation x t statistic) was used by 95% percentile.

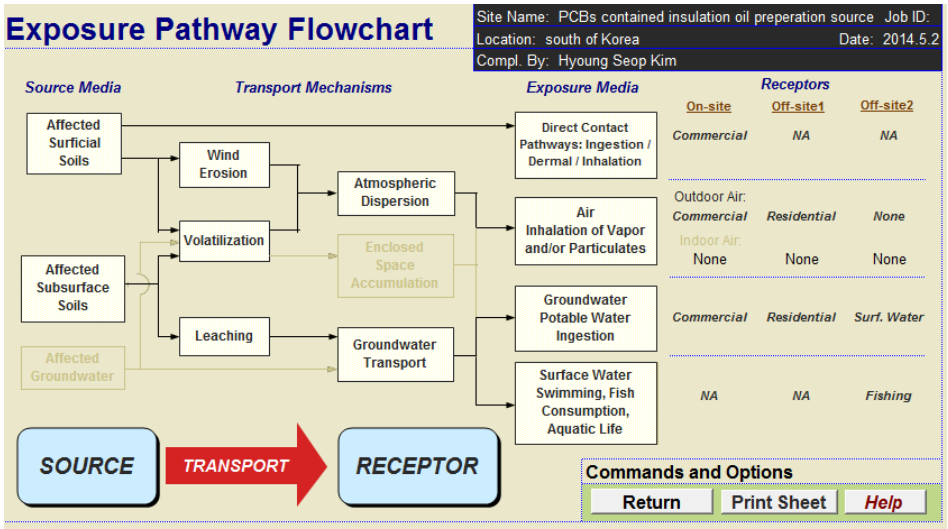

Fig. 1. Exposure pathway flowchart of PCBs in the vicinity of insulating oil recycling facility

Chemical and toxicity data of PCBs were referred to Texas Risk Reduction Program and USEPA Integrated Risk Information System(IRIS), etc. Transport modeling of outdoor air volatilization and was used to ASTM surface soil volatilization model(ASTM, 2000; Eqns. CM-1c/d and CM-2b) and only surface soil volatilization was considered with the exception of subsurface soil volatilization. Transport modeling of Soil-to-groundwater leaching was applied to ASTM soil attenuation model(ASTM, 200; Equn.CM-7, CM-8 and CM-10) which accounts for attenuation of target concentrations due to sorption to clean intervening soils between the soil

source zone and groundwater. Input data of average annual precipitation was 14.79 cm/yr and predominant soil type was applied with CLEA-UK loam. 940 day of PCBs half-life in soil was referred to Technical Support Document for Exposure Assessment and Stochastic Analysis issued by California office of environmental health hazard assessment.

Table 1. Summary of exposure parameters for the operating RBCA Tool Kit

Exposure Parameters		Residential				Commercial/Industrial	
		Child*	Adolescent	Adult	Age Adjusted**	Adult	Construct.
ATc	Averaging time for carcinogens (yr)	70	70	70	*NA*	70	70
ATn	Averaging time for non-carcinogens (yr)	6	12	30	*NA*	25	1
BW	Body weight (kg)	10	30	60	*NA*	60	60
ED	Exposure duration (yr)	6	12	30	*NA*	25	1
t	Averaging time for vapor flux (yr)	30	30	30	*NA*	30	30
EF	Exposure frequency (days/yr)	350	350	350	*NA*	250	180
EFD	Exposure frequency for dermal exposure	350	350	350	*NA*	250	180
IRw	Ingestion rate of water (L/day)	1	1	2	2.8	1	*NA*
IRs	Ingestion rate of soil (mg/day)	200	200	100	440	50	100
SA	Skin surface area (dermal) (cm^2)	2023	2023	3160	5310	3160	3160
M	Soil to skin adherence factor	0.5	0.5	0.5	*NA*	0.5	0.5
IRfish	Ingestion rate of fish (kg/yr)	0.049	0.049	0.049	0.118	*NA*	*NA*
FIfish	Contaminated fish fraction (unitless)	1	1	1	*NA*	*NA*	*NA*
IRbg	Below-ground vegetable ingestion	0.3339	0.3339	0.6677	327.208	*NA*	*NA*
IRabg	Above-ground vegetable ingestion	0.0894	0.0894	0.1787	87.598	*NA*	*NA*
VGbg	Above-ground Veg. Ingest. Correction Factor	0.01	0.01	0.01	*NA*	*NA*	*NA*
VGabg	Below-ground Veg. Ingest. Correction Factor	0.01	0.01	0.01	*NA*	*NA*	*NA*

Soil characteristics and PCBs concentration

The range of soil pH in the site was 4.5 to 6.4 and that of soil organic content was 0.2 to 3.4 percentages. Soil texture was mostly sandy loam and its clay content was 8 to 13 percentages. Geometric mean of PCBs(n=20) was 0.021 mg/kg and depth to top of affected soil was assumed to 1 m with aspects of concentration of PCBs in depth of soil. Those directly measured values of soil characteristics and PCBs concentrations were inputted to the RBCA Tool Kit.

Table 2. Total PCBs concentrations of the site

Sampling points	Soil depth	Conc. of total PCBs (mg/kg)	Sampling points	Soil depth	Conc. of total PCBs (mg/kg)
1	0~15cm	0.0097	6	0~15cm	N.D.
2	0~15cm	0.1413.	7	0~15cm	N.D.
3	0~15cm	ND		15~30cm	N.D.
	15~30cm	0.0168		30~50cm	N.D.
	30~50cm	0.0107		50~70cm	N.D.
	50~70cm	0.0111		70~90cm	N.D.
	70~90cm	0.0058	8	0~15cm	N.D.
4	0~15cm	N.D.			

5	0~15cm	0.0268
	15~30cm	0.0257
	30~50cm	0.0278
	50~70cm	0.0329
	70~90cm	0.0367

Risk assessment

Table 3 presents a summary table of baseline risk values for all applicable pathways. We found that carcinogenic risk(5.6E-8) was much lower than target risk(1.0E-5) and risk limit was not exceeded. Hazard quotient(3.9E-3) based toxic effects was also below than applicable limit (1.0). PCBs exposure concentration was below worrisome level of soil contamination of Korea, so, risk is estimated to be low.

Table 3. Output of risk summary table from RBCA Tool Kit

	BASELINE CARCINOGENIC RISK					BASELINE TOXIC EFFECTS				
	Individual COC Risk		Cumulative COC Risk		Risk	Hazard Quotient		Hazard Index		Toxicity
EXPOSURE PATHWAY	Maximum Value	Target Risk	Total Value	Target Risk	Limit(s) Exceeded?	Maximum Value	Applicable Limit	Total Value	Applicable Limit	Limit(s) Exceeded?
OUTDOOR AIR EXPOSURE PATHWAYS										
	1.1E-9	1.0E-5	1.1E-9	NA	No	NC	1.0E+0	NC	NA	No
SOIL EXPOSURE PATHWAYS										
	5.6E-8	1.0E-5	5.6E-8	NA	No	3.9E-3	1.0E+0	3.9E-3	NA	No
GROUNDWATER EXPOSURE PATHWAYS										
	NC	1.0E-5	NC	NA	No	NC	1.0E+0	NC	NA	No
SURFACE WATER EXPOSURE PATHWAYS										
	NC	1.0E-5	NC	NA	No	NC	1.0E+0	NC	NA	No
CRITICAL EXPOSURE PATHWAY (Maximum Values From Complete Pathways)										
	5.6E-8	*1.0E-5*	*5.6E-8*	*NA*	No	*3.9E-3*	*1.0E+0*	*3.9E-3*	*NA*	No
	Soil		*Soil*			*Soil*		*Soil*		

References:

1. NIER (2008); *Assessment for characteristic of PCBs contamination in soil*
2. Ministry of Environment (2002); *Korean Soil Contamination Public Testing Protocol*
3. SSSA (1996); *Methods of Soil Analysis*
4. NIER (2007); *Korean Persistent Organic Pollutant Public Testing Protocol*
5. NIER (2002); *Endocrine Distrupting Chemical Analysis Protocol*
6. U.P.B Sci. Bull., Series B, Vol 75, Iss. 1, 2013
7. California office of environmental health hazard assessment(2000); Technical Support Document for Exposure Assessment and Stochastic Analysis
8. Statistics Korea(2012) ; Korea Statistical Yearbook of 2012
9. Cal EPA(2003); Risk assessment of polychlorinated biphenyls at hazardous waste sites