CANCER RISK ASSESSMENT FOR PCBs IN TURKEY

MUNGAN ARDA Meral*, IMAMOGLU Ipek [1]

[1]Middle East Technical University, Ankara, Turkey, *meral.mungan@gmail.com

Introduction:
Polychlorinated Biphenyls (PCBs) were primarily used as dielectrics fluid in thermal insulation in electric production and transmission sector (closed uses). They were also used in various other open and semi-open uses such as in adhesives, construction insulating materials, dyes, etc. [1]. They were later discovered to accumulate in living organisms through scientific research first published in 1966 by Jensen [2], then in continuing studies that prove widespread presence of PCBs in ecosystems around the world and various organisms containing PCBs in their tissues (such as fish, human and chicken). As a result of the scientific information being available in terms of adverse effects of PCBs, their production and use were banned in 1979 in the USA[3] and later in many other countries. Research revealing characteristics of PCBs in terms of cancer mechanisms yielded the result of defining PCBs as "known human carcinogens" by International Agency for Research on Cancer (IARC) in 2013, where PCBs were determined as Group 1 carcinogens [4]. The scope of this study was to carry out a cancer risk assessment for environmental PCBs in Turkey, through the use of measured level of PCBs in Turkey in environmental compartments such as soil, biota and air.

Materials and methods:
USEPA Method. USEPA has been working on risk assessment since the days where the applied methodology was not formally recognized as "risk assessment". USEPA prepared its first risk assessment in December 1975, which was "Quantitative Risk Assessment for Community Exposure to Vinyl Chloride". Since then, USEPA integrated risk assessment as part of regulatory processes. Hence, the agency became the leader institution in provision of a general framework to be followed in analyzing cancer risks of carcinogens, pesticides and many chemicals including PCBs [5].

In 1980's, USEPA prepared Integrated Risk Information System (IRIS), a database of various substances that may ultimately affect human health due to exposure. USEPA's carcinogenic risk assessment guidelines in 1986 was published, afterwards. This methodology of carcinogenic risk assessment developed and improved by USEPA over the years; it may be stated that USEPA mainly introduces different exposure pathways to any substance of health risk concern: ingestion, inhalation and dermal exposure.

USEPA developed regional screening levels (RSLs) based on the overall background developed over the years, that provide health risk assessment-based analysis derived from standardized equations combining exposure information assumptions with USEPA toxicity data. Screening Levels (SLs) are considered by the Agency to be protective for humans (including sensitive groups) over a lifetime. They do not consider ecological risk assessment [6]. SLs carry out risk assessment over standardized equations for the following scenarios: 1. Resident, 2. Indoor Worker, 3. Composite Worker, 4. Construction Worker, 5. Fish, 6. Soil to Groundwater, 7. Recreator.

The equations in Residential Screening Levels web site of USEPA are mainly the same as the equations referred in USEPA carcinogenic health risk guidelines; however, more accuracy is achieved through the introduction of units such as Particulate Emission Factor and Inhalation Unit Rate. Screening Levels Web Site also has a calculator for risk with these formulas, as well.

PCBs have 209 congeners. Any commercial mixture is a combination of these congeners and the analysis of a commercial mixture and environmental PCBs that could be found in sediments, groundwater, etc. is expected to be different from each other due to environmental weathering mechanisms as well as biological degradation. Different ways of intake of PCBs into the body then would yield the same circulation within human body. As per the methodology for dose response assessment of PCBs, there is a "tiered approach that can use site-specific congener information when available, but can be adapted if information is limited to total PCBs encountered through each exposure pathway [7]". Findings for health risk for individual congeners were similar to the findings for total PCBs in certain studies [8], while some of the congeners are criticized to be less clear; and there are reference studies carrying out health risk assessment for PCBs over total PCB concentrations [9], [10]. Thus, in this study we carried out a risk assessment over total PCB concentrations, due to limited data and limitations in TEF approach referred in "PCBs: Cancer Dose Response Assessment and Application to Environmental Mixtures" Guideline of USEPA (1996). As per the mentioned references, the risk assessed through total PCB concentrations may be lower than congener-based risk assessment.

Equations. This study will use the SLs approach of USEPA that takes into account the standardized equations in carcinogenic risk assessment guidelines for dose-response relations for the following scenarios: 1. Resident and 2. Fish

Scenario 1 - Resident

"This receptor spends most, if not all, of the day at home. The activities for this receptor involve typical home making chores (cooking, cleaning and laundering) as well as outdoor activities. The resident is assumed to be exposed to contaminants via the following pathways: incidental ingestion of soil, dermal contact with soil, inhalation of volatiles and fugitive dust. Adults and children exhibit different ingestion rates for soil." [6]. The study only considered cancer risk assessment within these scenarios, without considering non-cancer hazard indexes into consideration. Since PCBs are not in the category of mutagenic substances, the equations for mutagenicity were also not included.

Soil:

These equations below provide concentration and cancer risk relation for exposure to soil through ingestion, dermal and inhalation routes:

Ingestion[6]:

$$\mathrm{SLres-soil-ca-ing}\left(\frac{\mathrm{mg}}{\mathrm{kg}}\right)=\frac{\mathrm{TRxATres}\left(365\left(\frac{\mathrm{days}}{\mathrm{year}}\right)\mathrm{xLT}(70\mathrm{years}\right)}{\mathrm{CSFo}\left(\frac{\mathrm{mg}}{\mathrm{kg-day}}\right)^{-1}xRBAxIFSres-adj\left(36{,}750\frac{mg}{kg}\right)x\left(10^{-6}\frac{kg}{mg}\right)}$$

where

$$IFSres-adj\left(36{,}750\,\frac{mg}{kg}\right)=\left(\frac{\mathrm{EFres-c}\left(\frac{350\mathrm{days}}{\mathrm{year}}\right)\mathrm{xEDres-c(6\ years)xIRSres-c}\left(200\frac{\mathrm{mg}}{\mathrm{day}}\right)}{\mathrm{BWres-c(15\ kg)}}+\frac{\mathrm{EFres-a}\left(\frac{350\mathrm{days}}{\mathrm{year}}\right)\mathrm{xEDres(26\ years)-EDres-c(6\ years)xIRSres-a}\left(100\frac{\mathrm{mg}}{\mathrm{day}}\right)}{\mathrm{BWres-a(80\ kg)}}\right)$$

Dermal[6]:

$$\mathrm{SLres-soil-ca-der}\left(\frac{\mathrm{mg}}{\mathrm{kg}}\right)=\frac{\mathrm{TRxATres}\left(365\left(\frac{\mathrm{days}}{\mathrm{year}}\right)\mathrm{xLT(70years)}\right)}{\frac{\mathrm{CSFo}\left(\frac{\mathrm{mg}}{\mathrm{kg-day}}\right)^{-1}}{GIABS}xDFSres-adj\left(103{,}390\frac{mg}{kg}\right)ABSdx\left(10^{-6}\frac{kg}{mg}\right)}$$

$$DFSres-adj\left(103{,}390\frac{mg}{kg}\right)=\left(\frac{\mathrm{EFres-c}\left(\frac{350\mathrm{days}}{\mathrm{year}}\right)\mathrm{xEDres-c(6\ years)xSAres-c}\left(2373\frac{\mathrm{cm2}}{\mathrm{day}}\right)xAFres-c\left(0.2\frac{mg}{cm2}\right.}{\mathrm{BWres-c(15\ kg)}}+\frac{\mathrm{EFres-a}\left(\frac{350\mathrm{days}}{\mathrm{year}}\right)\mathrm{xEDres(26\ years)-EDres-c(6\ years)xSAres-a}\left(6032\frac{\mathrm{cm2}}{\mathrm{day}}\right)\mathrm{xAFres-a}\left(0.07\frac{\mathrm{mg}}{\mathrm{cm2}}\right)}{\mathrm{BWres-a(80\ kg)}}\right)$$

Inhalation[6]:

$$\mathrm{SLres-soil-ca-inh}\left(\frac{\mathrm{mg}}{\mathrm{kg}}\right)=\frac{\mathrm{TRxATres}\left(365\left(\frac{\mathrm{days}}{\mathrm{year}}\right)\mathrm{xLT(70years)}\right)}{\mathrm{IUR}\left(\frac{\mathrm{ug}}{\mathrm{m3}}\right)^{-1}x1000\frac{ug}{mg}xEFres\left(\frac{350\mathrm{days}}{\mathrm{year}}\right)x\left(\frac{1}{VFulim\left(\frac{m3}{kg}\right)}+\frac{1}{PEF\left(\frac{m3}{kg}\right)}\right)xEDres(26\ years)xETres\left(\frac{24hours}{1\ day}x\frac{1\ day}{24hours}\right)}$$

Air [6]**:**

The following equation defines concentration and cancer risk relation for exposure to air:

$$\mathrm{SLres-air-ca}\left(\frac{\mathrm{ug}}{\mathrm{m3}}\right)=\frac{\mathrm{TRxATres}\left(365\left(\frac{\mathrm{days}}{\mathrm{year}}\right)\mathrm{xLT(70years)}\right)}{\mathrm{EFres}\left(\frac{350\mathrm{days}}{\mathrm{year}}\right)\mathrm{xEDres(26\ years)x}ETres\left(\frac{24hours}{1\ day}x\frac{1\ day}{24hours}\right)x\mathrm{IUR}\left(\frac{\mathrm{ug}}{\mathrm{m3}}\right)^{-1}}$$

Scenario 2 – Fish [6]

The following equation defines concentration and cancer risk relation for exposure to biota as food source. The equation for fish consumption does not take into consideration age adjustment. Levels are calculated for fish tissue.

$$\mathrm{SLres-fish-ca-ing}\left(\frac{\mathrm{mg}}{\mathrm{kg}}\right)=\frac{\mathrm{TRxATres}\left(365\left(\frac{\mathrm{days}}{\mathrm{year}}\right)\mathrm{xLT(70years)}\right)\mathrm{xBWres-a(80kg)}}{\mathrm{EFres-a}\left(\frac{350\mathrm{days}}{\mathrm{year}}\right)\mathrm{xEDres(26\ years)}x\mathrm{CSFo}\left(\frac{\mathrm{mg}}{\mathrm{kg-day}}\right)^{-1}xIRFresa\left(\frac{mg}{day}\right)x\left(\frac{10^{-6}kg}{1mg}\right)}$$

*Data***.** There is no systematic database for monitoring of environmental PCBs, or there are no systems for a health risk study framework for exposure to PCBs in Turkey. Thus, we established a database of PCB levels reported in the scientific literature for Turkey, and these data were used during all calculations.

Calculations. For Scenario 1 and Scenario 2, IRIS database and USEPA Regional Screening Level calculation parameters and their values are used [6]. However, for fish ingestion rate calculation, the fish consumption information for Turkey is used [11]. The highest total PCB concentrations are used to work these two scenarios under worst case conditions.

In all equations for RSL in the USEPA web page, the Target Risk is taken as 10^{-6} as tolerable risk and pertaining screening level for substances are calculated. In this study, it is done vice versa, the concentration values from our current database for PCB levels in Turkey is used and the Cancer Risk Value is calculated.
Since there are no unified laboratory data to support this study, and since our database is established through literature search of various academic studies in Turkey on PCB concentrations in environmental media, total PCB concentrations are used in health risk assessment rather than congener-specific PCB concentrations.

Results and Discussion:

As a result of the analysis carried out on the following scenarios, a large portion of the cancer risk calculations in Turkey, based on our database, showed results higher than tolerable cancer risk values for Resident soil exposure for soil PCB concentrations, Resident air exposure for air PCB concentrations, and Fish ingestion. This result is significant because Turkey was never a producer of PCBs. Our results show that their import for many applications throughout the country have resulted in accumulation of PCBs in various environmental compartments that pose a health risk in the country.

Analyses were carried out for soil, air and fish data for Turkey and compared with other countries that produced and/or managed PCB pollution. An example comparison is presented below for health risk assessment for exposure to soil on the grounds of Resident scenario in Turkey, together with those from Czechia and USA in remediated sites after PCB pollution (such as Superfund sites). The risk categorization used is given in Table 1, which is mainly in alignment with US EPA risk characterization [12] Table 2 provides cancer risk assessment resulting in “high” risk for soil exposure under resident scenario. Results show that certain risk values in Turkey are higher than remediated sites in Czechia and USA. Results indicate that proper management of contaminated sites is urgently required in Turkey because the calculated cancer risk is not tolerable for certain unmanaged sites.

Table 1. Risk Categorization[12]

Risk	Risk Categorization
$CR \geq 10^{-1}$	Very High
$10^{-3} < CR < 10^{-1}$	High
$10^{-4} < CR \leq 10^{-3}$	Moderate
$10^{-6} < CR \leq 10^{-4}$	Low
$CR \leq 10^{-6}$	Very Low

Table 2. A summary of results for resident soil exposure for soil PCB concentrations of this study compared with corresponding risk studies conducted in Czechia [13] [14] and USA [15]

Research Number	Location	Reference	Environmental Medium	Highest measured concentration ∑PCBs (mg/kg)	Cancer Risk
1	Horozgediği Village, Aliağa	16	Soil	805,00	3,54E-03
2	Dilovası, Kocaeli	17	Soil	1676,00	7,36E-03
3	Tuzla firestation	13	Soil	0,88	2,53E-06
4	Kragujevac Zastava	13	Soil	0,20	5,75E-07
5	Kragujevac FN	13	Soil	3,09	8,89E-06
6	Zadar Transformer	13	Soil	0,24	6,90E-07
7	Spolana Archive	13	Soil	0,07	2,01E-07
8	Spolana Gate	13	Soil	0,90	2,59E-06
9	Lhenice Dumpsite	14	Soil	135,90	3,91E-04
10	USA, IOWA	15	Soil	1,20	3,45E-06

Turkey has ratified the Stockholm Convention in 2010 and since then submitted national implementation plans to the Secretariat. As part of the process, Turkey is currently preparing to start a nation-wide monitoring plan for POPs. A nation-wide monitoring study would provide valuable spatial data which could then be used for a comprehensive risk assessment. Since, currently such spatially resolved PCB levels are not available, this study can only investigate the risk levels of the cities in which scientific studies were conducted. Therefore, the provincial distribution is biased, i.e. showing Aliağa and Kocaeli to be the provinces having the highest cancer risk. As monitoring data with proper spatial resolution becomes available, congener-specific risk assessment studies covering all of Turkey will be possible.

Even though the worst-case scenarios were studied with the highest values from the literature, this is the first study that attempts risk assessment of PCBs in Turkey which shows that in highly populated and/or highly industrialized cities in Turkey, cancer risk due to PCBs is of concern. Systematic monitoring of all POPs to reveal environmental levels in a variety of media would enable better and more informed decisions on chemicals to be made by the Turkish government.

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