

$$\text{Hazard Index} = \text{HI} = \sum_{n=1}^{13} \text{HQ}_{\text{dermatological,ingestion,inhalation}}$$

$$\text{HQ}_{\text{dermatological,ingestion,inhalation}} = \frac{\text{CDI}_{\text{dermatological,ingestion,inhalation}}}{\text{RfD}_{\text{dermatological,ingestion,inhalation}}}$$

$$\text{CDI}_{\text{ingestion}} = \frac{C_t \times \text{CF} \times \text{IR}_s \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

$$\text{CDI}_{\text{dermal}} = \frac{C_t \times \text{CF} \times \text{SA} \times \text{AF} \times \text{ABS} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

$$\text{CDI}_{\text{inhalation}} = \frac{C_t \times \frac{1}{\text{PEF}} \times \text{IR}_a \times \text{ET} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

Table 1 Factors used in calculation of CDI.

	<b>Factor</b>	<b>Explanation</b>	<b>Unit</b>	<b>Children</b>	<b>Man/Woman</b>
RfD	$C_t$	Element amount	$\frac{\text{mg}}{\text{kg}}$	-	-
	$\text{IR}_s$	Ingestion rate of soil	$\frac{\text{mg}}{\text{day}}$	200	100
	SA	Skin surface area	$\frac{\text{cm}^2}{\text{day}}$	2373	6032
	AF	Adherence factor	$\frac{\text{mg}}{\text{cm}^2}$	0.2	07
	$\text{IR}_a$	Inhalation rate of soil	$\frac{\text{m}^3}{\text{hour}}$	0.53	0.83
	ED	Exposure duration	Year	6	20
	BW	Bodyweight	Kg	18	77/67
	AT	Average time	Day	365xED	365xED
	PEF	Particle emission factor	$\frac{\text{m}^3}{\text{kg}}$		1.36 x 10 <sup>9</sup>
	CF	Conversion multiplier	$\frac{\text{kg}}{\text{mg}}$		1x10 <sup>-6</sup>
	ET	Exposure time	$\frac{\text{hour}}{\text{day}}$		24
	EF	Exposure frequency	$\frac{\text{day}}{\text{year}}$		350
	ABS	Absorption	-		Arsenic 0.3 Other 0.1

$$\frac{[\text{RfC (mg/m}^3\text{)} \times 20 \text{ m}^3\text{/day (Daily inhalation rate)}]}{70 \text{ kg (bodyweight)}} = \text{RfD} \left( \frac{\text{mg}}{\text{kg} \times \text{day}} \right)$$

Table 2 RfD Values of Elements ( $\frac{\text{mg}}{\text{kg} \times \text{day}}$ ) (IC = IRIS (Integrated Risk Information System); AF = ATSDR Final (Agency for Toxic Substances and Disease Registry); C = CALEPA (California Environmental Protection Agency))

Element	RfD Ingestion (mg/kg-day)	RfD Ingestion/Dermal reference	RfC Inhalation (mg/m <sup>3</sup> )	RfC Inhalation Reference	RfD Dermal	Health problem
Antimony	4.00E-04	IC	3.00E-04	AF	8.00E-05	Metabolic
Arsenic	3.00E-04	IC	1.50E-05	C	6.00E-05	Cardiovascular
Barium	2.00E-01	IC	5.00E-04	AF	4.00E-02	Renal
Beryllium	2.00E-03	IC	2.00E-05	IC	4.00E-04	Respiratory
Cadmium	1.00E-04	AF	1.00E-05	AF	2.00E-05	Muscular
Cobalt	3.00E-04	AF	6.00E-06	AF	6.00E-05	Hematologic
Lead and compounds	3.50E-03	C	-		7.00E-04	Neurologic
Molybdenum	5.00E-03	IC	2.00E-03	AF	1.00E-03	Renal
Nickel and compounds	1.10E-02	C	1.40E-05	C	2.20E-03	Respiratory
Selenium	5.00E-03	IC	2.00E-02	C	1.00E-03	Renal
Tin	6.00E-01	AF	-	-	1.20E-01	Hematologic
Zinc and compounds	3.00E-01	IC	-	-	6.00E-02	Hematologic

## Carcinogenic Risk

$$Risk = CDI \times CSF_{\text{dermal,ingestion,inhalaion}}$$

$$Total\ Carcinogenic\ Risk = \sum_{n=1}^5 Risk$$

- High risk value:  $Risk > 10^{-4}$
- Acceptable risk value:  $10^{-4} < Risk < 10^{-6}$

Table **Error! No text of specified style in document..**1 Carcinogenic Slope Factors

Element	CSF <sub>Ingestion</sub>	CSF <sub>Dermal</sub>	CSF <sub>Inhalation</sub>	Reference Agencies
Arsenic	1.5	7.5	15.1	USEPA
Beryllium	-	-	8.4	USEPA
Cadmium	-	-	6.3	USEPA
Nickel	0.91	4.55	0.91	CALEPA
Lead	0.85	0.425	0.42	CALEPA

## Descriptive Statistics

Table 3 Crustal and soil averages of elements and trigger action values for these elements (Kabata-Pendias, 2011), World soil averages (Kabata-Pendias, 2011), European upper layer soil averages (FOREGS, 2005), Izmir city center's soil and sediment averages, Izmir city center's rock averages in ppm (this study).

<b>Element</b>	<b>Crust Average (ppm)</b>	<b>World Soil Average (ppm)</b>	<b>FOREGS Europe (ppm)</b>	<b>İzmir Soil and Sediment Average (ppm)</b>	<b>İzmir Rock Average (ppm)</b>	<b>Trigger Action Value (ppm)</b>
Arsenic, As	1.8	6.83	11.6	45.51	39.83	65
Barium, Ba	400	460	400	232.11	145.29	400
Beryllium, Be	3	1.34	2	1.19	0.72	10
Bromine, Br	2	10	-	4.22	0.69	-
Cadmium, Cd	0.1	0.41	0.28	0.29	0.08	20
Cobalt, Co	10	11.3	10.4	13.72	8.42	2
Chromium, Cr	100	59.5	94.8	33.13	16.58	50
Chlorine, Cl	640	300	380	104.54	12.55	-
Copper, Cu	55	38.9	17.3	28.55	37.04	60
Fluorine, F	625	321	264	16.29	21.98	-
Mercury, Hg	0.07	0.07	0.061	0.16	0.08	1.5
Iodine, I	0.5	2.8	2.4	0.16	0.08	-
Lithium, Li	20	21	-	15.53	15.03	-
Manganese, Mn	900	488	524	686.77	480.82	-
Molybdenum, Mo	1.5	1.1	0.94	1.75	0.99	5
Nickel, Ni	20	29	37	35.18	20.27	75
Lead, Pb	15	27	32	56.66	54.68	50
Antimony, Sb	0.2	0.67	1.04	2.55	0.88	10
Selenium, Se	0.05	0.44	-	0.4	0.17	3
Tin, Sn	2.5	2.5	4.5	2.61	0.99	35
Vanadium, V	135	129	60	54.03	48.35	100
Zinc, Zn	70	70	68.1	94.87	39.46	200

**Table Error! No text of specified style in document.** Descriptive statistics of potentially toxic elements in Upper Layer (0-10 cm).

	As (ppm)	Ba (ppm)	Be (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Sb (ppm)	Se (ppm)	Sn (ppm)	Zn (ppm)
Detection Limit	0.01	0.5	0.01	0.001	0.001	0.01	0.01	0.04	0.005	0.005	0.003	0.01	0.1
Mean	41	201.1	1.2	0.3	13.6	39.4	2.2	39.9	52.6	2.4	0.3	2.5	103.2
Median	17.1	209	1	0.1	12.9	26.3	0.6	27.2	29.8	0.7	0.1	1.4	64.9
Std. Deviation	73.9	78.1	0.6	0.6	4.8	36.1	9	35.6	83.2	5.2	0.5	3.8	106.1
Range	324.6	393	2.7	3	21.9	155.9	58.1	148.6	474.3	26.4	2.2	21.9	572.4
Minimum	1.4	47	0.3	0.3	2.4	8.1	0.2	2.4	11.7	0.2	0.02	0.3	17.6
Maximum	326	440	2.9	3	24.3	164	58.3	151	486	26.6	2.2	22.2	590
MAC <sup>a</sup>	20	n.d.	10	5	50	200	10	60	300	10	n.d.	n.d.	300
TAV <sup>b</sup>	30	600	300	20	100	450	20	20	300	50	10	50	1500
Average Soil <sup>b</sup>	6.83	460	1.34	0.41	11.3	59.5	1.1	29	27	0.67	0.44	2.5	70
Percentiles													
10 <sup>th</sup>	5.1	96.6	0.7	0.05	8.4	12	0.3	8.1	15.6	0.3	0.04	0.7	37.1
50 <sup>th</sup>	17.1	209	1	0.1	12.9	26.3	0.6	27.2	29.8	0.7	0.1	1.4	64.9
90 <sup>th</sup>	84.5	309	2	0.6	20.8	107	2.4	86.8	84.9	4.4	1.3	6.3	208

(a) Maximum allowable concentration (MAC) values can be found commonly in the literature, compiled from Kabata-Pendias and Sadurski (2004). (b) Trigger action values (TAV) proposed in some European countries and average soil content Kabata-Pendias (2011).

**Table 5** Descriptive statistics of potentially toxic elements in Intermediate Layer (10-30 cm).

	As (ppm)	Ba (ppm)	Be (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Sb (ppm)	Se (ppm)	Sn (ppm)	Zn (ppm)
Detection Limit	0.01	0.5	0.01	0.001	0.001	0.01	0.01	0.04	0.005	0.005	0.003	0.01	0.1
Mean	33.8	269.2	1.2	0.3	30.2	13.6	1.4	33.7	57.0	2.1	0.3	3.0	94.3
Median	14.6	211.5	1.0	0.1	26.1	13.3	0.5	20.4	27.8	0.7	0.1	1.5	67.9
Std. Deviation	60.4	227.2	0.4	0.5	20.3	5.2	3.4	31.2	80.7	4.0	0.5	6.0	121.3
Range	350.7	1381	1.9	2.5	99.4	30.5	17.5	150.7	330.9	22.8	2.5	29.9	765
Minimum	3.4	44.0	0.6	0.01	6.6	1.7	0.1	5.3	9.1	0.2	0.02	0.3	16.4
Maximum	354.0	1425	2.5	2.6	106.0	32.2	17.6	156.0	340	23.0	2.5	30.2	782
MAC <sup>a</sup>	20	n.d.	10	5	50	200	10	60	300	10	n.d.	n.d.	300
TAV <sup>b</sup>	30	600	300	20	100	450	20	20	300	50	10	50	1500
Average Soil <sup>b</sup>	6.83	460	1.34	0.41	11.3	59.5	1.1	29	27	0.67	0.44	2.5	70
Percentiles													
10 <sup>th</sup>	5.2	86.2	0.8	0.04	13.4	0.04	0.2	8.7	13.5	0.4	0.02	0.5	34.0
50 <sup>th</sup>	14.6	211.5	1.0	0.1	26.1	0.1	0.5	20.4	27.8	0.7	0.1	1.5	67.9
90 <sup>th</sup>	71.8	548.5	1.9	0.54	61.6	0.6	2.2	81.6	223.0	7.2	0.7	4.9	134.3

(a) Maximum allowable concentration (MAC) values can be found commonly in the literature, compiled from Kabata-Pendias and Sadurski (2004). (b) Trigger action values (TAV) proposed in some European countries and average soil content Kabata-Pendias (2011).

Table 6 Descriptive statistics of potentially toxic elements (ppm) in Bottom Layer (30-50 cm)

	As (ppm)	Ba (ppm)	Be (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Sb (ppm)	Se (ppm)	Sn (ppm)	Zn (ppm)
Detection Limit	0.01	0.5	0.01	0.001	0.001	0.01	0.01	0.04	0.005	0.005	0.003	0.01	0.1
Mean	42.8	215.2	1.2	0.3	14.8	31.9	1.7	35.1	52.4	2.4	0.4	2.5	91.9
Median	16.0	196.5	1.0	0.1	12.9	22.4	0.6	20.7	29.8	0.8	0.1	1.3	64.2
Std. Deviation	95.6	123	0.7	0.4	8.0	33.7	3.8	40.9	58.8	4.0	1.0	4.3	132.7
Range	607.5	708	3.2	2.1	40.2	227.5	19.9	233.2	246.0	16.0	6.5	29.9	966.5
Minimum	2.5	54.8	0.2	0.02	1.1	1.5	0.1	1.8	10	0.1	0	0.4	13.5
Maximum	610	763	3.4	2.2	41.3	229	20	235	256	16.2	6.5	30.2	980
MAC <sup>a</sup>	20	n.d.	10	5	50	200	10	60	300	10	n.d.	n.d.	300
TAV <sup>b</sup>	30	600	300	20	100	450	20	20	300	50	10	50	1500
Average Soil <sup>b</sup>	6.83	460	1.34	0.41	11.3	59.5	1.1	29	27	0.67	0.44	2.5	70
Percentiles													
10 <sup>th</sup>	3.5	85.7	0.6	0.03	4.9	11.2	0.2	6.4	14.4	0.3	0.02	0.5	29.4
50 <sup>th</sup>	16.0	196.5	1.0	0.1	12.9	22.4	0.6	20.7	29.8	0.8	0.1	1.3	64.2
90 <sup>th</sup>	127.9	327	2.3	0.6	25.6	66.5	2.8	78.6	146	9.2	0.8	5.3	125.3

(a) Maximum allowable concentration (MAC) values can be found commonly in the literature, compiled from Kabata-Pendias and Sadurski (2004). (b) Trigger action values (TAV) proposed in some European countries and average soil content Kabata-Pendias (2011).