Heavy metals in soil and sand from playgrounds of Çanakkale city (Turkey), and related health risks for children

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Supplementary Materials

Health risk assessment model

The average daily dose (ADD) of heavy metals through ingestion, inhalation and dermal contact of soil and sand was calculated using equations (1)–(3) [1–4]:

$$ADD_{ingestion} = C \times \frac{IngR \times EF \times F \times ED}{BW \times AT} \times CF \tag{1}$$

$$ADD_{inhalation} = C \times \frac{InhR \times EF \times F \times ED}{PEF \times BW \times AT} \tag{2}$$

$$ADD_{dermal} = C \times \frac{SA \times AF \times ABS \times EF \times F \times ED}{BW \times AT} \times CF \tag{3}$$

where, C represents heavy metal contents (mg kg^{-1}) of soil and sand determined in this study; IngR is the ingestion rate set at the conservative value of 200 mg d^{-1} [5]; InhR is the inhalation rate set at InhR is the inhalation rate set at 8 m^3 day^{-1} for children [3]; SA is the skin surface available for exposure, 2800 cm^2 for children [6]; AF is the skin adherence factor, set at 0.2 mg cm^{-2} [6]; ABS is the dermal absorption factor (unitless), set at 0.001 [7,8]; EF is the exposure frequency (days year^{-1}), calculated in this study by following the rationale described in [7,8] as 204 days year^{-1} (assuming the conservative number of visits in a playground 7 days per week and subtracting 86 rainy days per year for the city and 30 days per year spent away from home); F is the fraction of time spent in a playground and set in this study at 0.1 (assuming the upper 95th percentile proposed by De Miguel et al. [7]; ED is the exposure duration, set in this study at 6 years for children [2]; ED is the exposure duration set at 6 years; CF is the conversion factor (10^{-6} kg mg^{-1}); BW is the average body weight at 15 kg [3]; AT is the averaging time, which equals ED x 365 days for non-carcinogenic effects [2];

PEF is the soil to air particle emission factor, in this study, 6.8×10^8 m^3 kg^{-1}, assuming absence of vegetative cover [7–9].

Tables

Table S1. Sampling sites and traffic density around the studied playgrounds.

Sample code	Sample site/ Playground	Coordinates		Traffic density[*]
		N	E	
S1	Ugur Mumcu	40º9'32''	26 º25'1''	Medium
S2	Esenler	40º9'44''	26 º25'5''	Medium
S3	Rotary	40º9'32''	26 º25'8''	Medium
S4	Esenkent Site	40º9'34''	26 º25'17''	Medium
S5	Ozlem Kayalı	40º9'48''	26 º25'20''	Low
S6	Esenler Sosyal Yasam Evi	40º9'53''	26 º24'51''	Medium
S7	Ozgurluk	40º9'45''	26 º24'29''	High
S8	Anafartalar	40º9'40''	26 º24'43''	Medium
S9	Can Dostlar	40º8'14''	26 º24'59''	Low
S10	Ahmet Taner Kıslalı	40º8'13''	26 º24'47''	High
S11	Cevatpasa	40º9'17''	26 º24'35''	Medium
S12	Halk Bahcesi	40º9'3''	26 º24'27''	High
S13	Eminkent	40º7'13''	26 º24'51''	High
S14	Resat Tabak	40º8'40''	26 º24'57''	Low

[*]Observations on traffic density on the roads around playgrounds were made for at least three hours per day, during three days per week (Monday, Thursday, and Friday) [10].

Table S2. Comparison of the certified and the measured values (mg kg^{-1}) for the soil (NIM-GBW07425) standard reference material (Mean ± Std. deviation; n = 3)

Metals	Certified values	Measured values	Recovery (%)
Fe	42100±600	39327±840	107±2
Cr	59.0±3.0	59.0±8.9	101±14
Cu	21.4±1.2	22.3±2.5	97±11
Mn	572±14	548±38	105±7
Ni	25.4±1.3	25.8±0.7	98±3
Pb	24.7±1.4	25.3±1.2	98±5
Zn	65.0±5.1	66.7±5.9	98±9

Table S3. Reference doses (RfDs) for ingestion (ing), inhalation (inh), and dermal contact (derm) of heavy metals ([7,8] and references therein)

Heavy metals	RfD ing (mg kg^{-1} d^{-1})	RfD inh (mg kg^{-1} d^{-1})	RfD derm (mg kg^{-1} d^{-1})
Cr	3.00E-03	2.86E-05	7.50E-05
Cu	4.00E-02	n.a.	2.40E-02
Mn	4.60E-02	1.43E-05	1.84E-03
Ni	2.00E-02	2.60E-05	8.00E-04
Pb	3.50E-03	1.00E-03	5.30E-04
Zn	3.00E-01	n.a.	6.00E-02

n.a.: not available

Table S4. Pearson correlation coefficient between physicochemical properties of soils and heavy metals contents

Parameters	Clay	Silt	Fine sand	Coarse sand	pH	EC	CaCO$_3$	SOM	Cu	Mn	Zn	Cr	Ni
Silt	0.15												
Fine sand	-0.71*	-0.66*											
Coarse sand	0.13	0.30	-0.63*										
pH	0.04	0.22	-0.19	0.15									
EC	0.41*	0.33*	-0.40*	0.04	-0.39*								
CaCO$_3$	-0.18	-0.15	0.31*	-0.33*	0.18	-0.36*							
SOM	-0.17	-0.33	0.32*	-0.15	-0.54*	0.36*	0.03						
Cu	-0.28	-0.10	0.07	0.32*	-0.14	-0.15	0.17	0.17					
Mn	0.13	0.29	-0.38*	0.37*	0.04	0.05	-0.34*	-0.30	0.07				
Zn	-0.27	0.17	-0.06	0.29	-0.21	0.02	-0.32*	0.06	0.21	0.71*			
Cr	-0.26	0.12	0.17	-0.10	-0.09	-0.20	0.01	-0.25	-0.06	0.44*	0.55*		
Ni	-0.25	-0.03	0.28	-0.25	-0.06	-0.22	0.12	0.17	-0.09	0.40*	0.46*	0.91**	
Pb	-0.06	0.18	-0.19	0.30	-0.11	0.08	-0.28	-0.12	0.15	0.69*	0.65*	0.27	0.25

EC: electrical conductivity, SOM: soil organic matter

*$p < 0.05$; **$p < 0.01$

Figures

[%] Clay 0-2 µm

90
80
70
60
50
40
30
20
10

Cl

SiCl

SaCl

ClLo   SiClLo

SaClLo

Lo

SiLo

SaLo

Sa LoSa   Si

[%] Silt 2-50 µm

10 20 30 40 50 60 70 80 90

90 80 70 60 50 40 30 20 10

[%] Sand 50-2000 µm

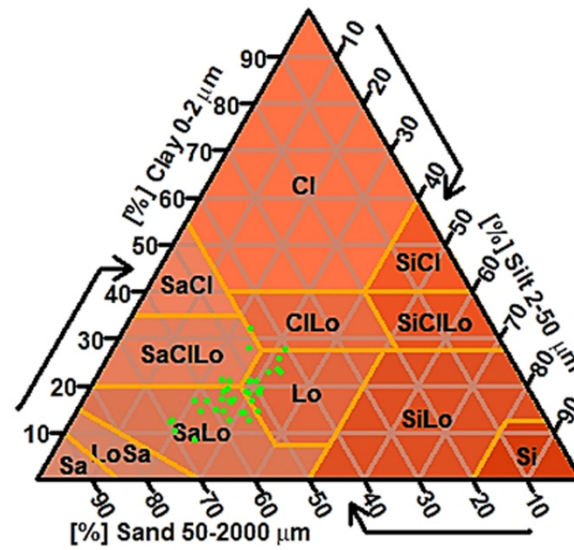**Figure S1.** Ternary diagram of soil classification scheme (after applying the USDA soil texture tool of ref. [11]).

(a)

Component 2

1.0
0.5
0.0
-0.5
-1.0

Cr
Ni
fine sand
Fe
Zn   Mn
Pb
Cu
SOM

-1.0 -0.5 0.0 0.5 1.0
Component 1

Component 3

(b)

Component 2

1.0
0.5
0.0
-0.5
-1.0

Ni
Cr
Zn
Cu   Mn
Pb
Fe   Fine sand
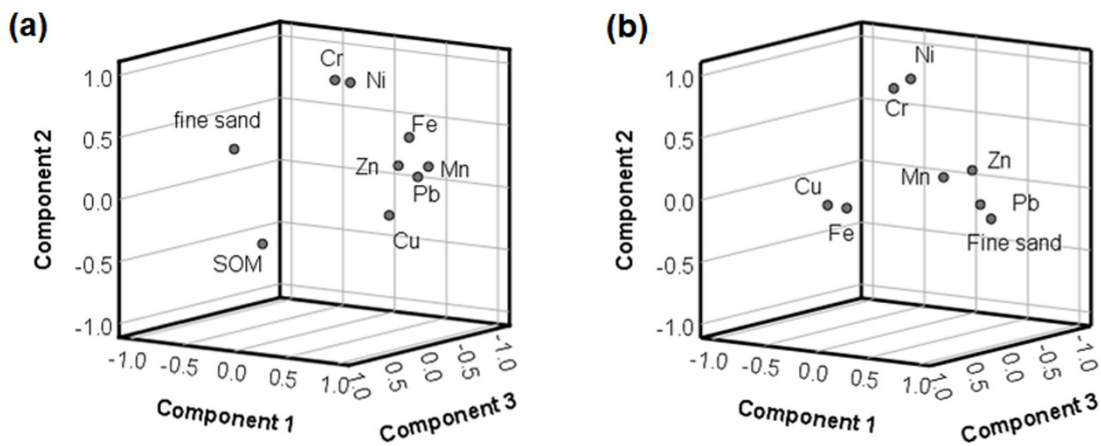
-1.0 -0.5 0.0 0.5 1.0
Component 1

Component 3

Figure S2. Component plots on rotated space after Factor Analysis of (a) the soil and (b) the sand samples.

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