

Toxic metals in soil depths from selected abandoned sites: Occurrence, sources, ecological and human health risk

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Supplementary Material

Table SM1. Values of variables for estimation of human health risk assessment

Variables	Unit	Definition	Values		References
			Child	Adult	
C	mg/kg	Metals concentration in soils			
ABS	-	Dermal absorption factor for metals	0.001	0.001	USEPA, 2011
AF	mg/cm ²	Soil to skin adherences factor	0.2	0.07	USEPA, 2011
BW	Kg	Average body weight	15	60	Iwegbue et al. (2020)
ED	Year	Exposure duration	6	30	USEPA, 2001
EF	day/yr	Exposure frequency	350	350	USEPA, 2001
ET	hr/day	Exposure time	8	8	USEPA, 1987
IngR	mg/day	Ingestion rate for receptor	200	100	USDOE, 2011
InhR	m ³ /day	Inhalation rate	12	50	USDOE, 2011
SA	cm ² /event	Skin surface area	2800	5700	USDOE, 2011
ATnc	D	Averaging time for non-carcinogenic	ED x 365		USDOE, 2011
ATca	d	Averaging time for carcinogenic	LT x 365		USDOE, 2011
LT	Year	Lifetime	55 years		WHO, 2018
PEF	m ³ /kg	Dust/Soil to air particulate emission factor	1.36 x 10 ⁹		USDOE, 2011
RfDo	(mg/kg/d)	Oral reference dose	Contaminant specific		Table SM4
RfDi		Inhalation reference dose	Contaminant specific		Table SM4
SFO	(mg/kg/d)	Oral slope factor	Contaminant specific		Table SM4
IUR	(µg/m ³)	Inhalation unit risk	Contaminant specific		Table SM4

Table SM2. Toxicological parameters of the investigated metals used for health risk assessment

Metals	Oral Ingestion Reference Dose (RfDo)	Inhalation Reference Dose (RfDi)	SFO _{ing} (mg/kg/d)	IUR (µg/m ³)	GIABS
Cd	1.0 x 10 ⁻³	1.0 x 10 ⁻⁵		1.8 x 10 ⁻³	0.025
Cr	3.0 x 10 ⁻³	1.0 x 10 ^{-4*}	5.0 x 10 ⁻³	1.2 x 10 ⁻²	0.013
Ni	2.0 x 10 ⁻²	9.0 x 10 ⁻⁵		2.6 x 10 ⁻⁴	0.04
Fe	7.0 x 10 ⁻¹				1
Zn	3.0 x 10 ⁻¹	4.0 x 10 ^{-3**}			1
Pb	3.5 x 10 ⁻³	2.0 x 10 ^{-4**}	8.5 x 10 ⁻³	1.2 x 10 ⁻⁵	1
Mn	1.4 x 10 ⁻¹	5.0 x 10 ^{-5*}			1
Cu	4.0 x 10 ⁻¹	1.4 x 10 ^{-3*}			1
Reference	USEPA (2012)	USEPA (2012)	USDOE (2011)	USEPA, (2010)	USEPA (2011)

* USEPA (1997); ** MOEE, 2008

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Table SM3. Significance of the contamination/pollution index, geoaccumulation index and enrichment factor

CPI values	Significance	Igeo Values	Significance	EF Values	Significance
<0.1	Very slight contamination	<0	Practically unpolluted (Class 1)	<2	Deficiency to minimal enrichment
0.10-0.25	Slight contamination	0-1	Unpolluted to moderately polluted (Class 2)	2-5	Moderate enrichment
0.26-0.50	Moderate contamination	1-2	Moderately polluted (Class 3)	5-20	Significant enrichment
0.51-0.75	Severe contamination	2-3	Moderately to strongly polluted (Class 4)	20-40	Very high enrichment
0.76-1.00	Very severe contamination	3-4	Strongly polluted (Class 5)	>40	Extremely high enrichment
1.10-2.00	Slight pollution	4-5	Strongly polluted to very polluted (Class 6)		
2.10-4.00	Moderate pollution	>5	Extremely polluted (Class 7)		
4.10-8.00	Severe pollution				
8.10-16.0	Very severe pollution				
>16.0	Excessive pollution				

Table SM4. Indices for interpretation of potential ecological risk for metal pollution (Håkanson, 1980)

Contamination factor (C_f)	Contamination factor for an individual metal	Degree of contamination (C_d)	Degree of contamination of the environment	E_r	Ecological risk factor for an individual metal	Potential ecological risk index (RI)	Pollution Degree
$C_f < 1$	Low	$C_d < 5$	Low contamination	$E_r < 40$	Low risk	$RI < 65$	Low risk
$1 \leq C_f < 3$	Moderate	$5 \leq C_d < 10$	Moderate contamination	$40 \leq E_r < 80$	Moderate risk	$65 \leq RI < 130$	Moderate risk
$3 \leq C_f < 6$	Considerable	$10 \leq C_d < 20$	Considerable contamination	$80 \leq E_r < 160$	Considerable risk	$130 \leq RI < 260$	Considerable risk
$C_f \geq 6$	High	$C_d \geq 20$	High contamination	$160 \leq E_r < 320$ $E_r \geq 320$	High risk Very high risk	$RI \geq 260$	Very high risk

Table SM5. Concentrations of metals (mg/kg) in the soils in comparison with quality guidelines (SQGs)

Metals	TEL	PEL	ERL	ERM	<TEL (%)	TEL-PEL (%)	>PEL (%)	<ERL	ERL-ERM (%)	>ERM (%)
Cd	0.68	4.2	1.2	9.6	0 (0)	11 (55)	9 (45)	0 (0)	17 (85)	3 (15)
Pb	30.2	112.2	46.7	218	20 (100)	0 (0)	0 (0)	20 (100)	0 (0)	0 (0)
Cr	52.3	160.4	81	370	20 (100)	0 (0)	0 (0)	20 (100)	0 (0)	0 (0)
Ni	15.3	42.8	20.9	51.6	8 (40)	3 (15)	9 (45)	10 (50)	2 (10)	8 (40)
Cu	18.7	180.2	34	270	3 (15)	17 (85)	0 (0)	9 (45)	11 (55)	0 (0)
Zn	124	271	150	410	20 (100)	0 (0)	0 (0)	20 (100)	0 (0)	0 (0)

Table SM6. t-Test: Paired Two Sample for Means

	TOPSOIL	SUBSOIL
Mean	953.8788	1131.6257
Variance	6919486	9824256
Observations	8	8
Pearson Correlation	0.999956	
Hypothesized Mean Difference	0	
df	7	
t Stat	0.996322	
P(T<=t) one-tail	0.17614	
t Critical one-tail	1.894579	
P(T<=t) two-tail	0.35228	
t Critical two-tail	2.364624	

Table SM7. ANOVA OF METALS FOR TOPSOIL

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6097314.4	9	677479.38	0.0904	0.9997141	2.017
Within Groups	524625121	70	7494644.6			
Total	530722436	79				

Table SM8. ANOVA OF METALS FOR SUBSOIL

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	19029203.37	9	2114356	0.180346	0.995541	2.016601
Within Groups	820673713	70	11723910			
Total	839702916.4	79				

Table SM9. Hazard index of trace metals

	CHILD				ADULT			
	HQIng	HQInh	HQDerm	HI	HQIng	HQInh	HQDerm	HI
APS1	0.13	0.002	0.01	0.15	0.02	0.01	0.002	0.03
APS2	0.2	0.004	0.02	0.22	0.02	0.02	0.003	0.04
PTF1	0.33	0.009	0.01	0.35	0.04	0.04	0.002	0.08
PTF2	0.23	0.006	0.01	0.25	0.03	0.02	0.002	0.05
SWD1	0.27	0.005	0.01	0.29	0.03	0.02	0.003	0.06

CHILD					ADULT			
	HQIng	HQInh	HQDerm	HI	HQIng	HQInh	HQDerm	HI
SWD2	0.3	0.007	0.01	0.32	0.04	0.03	0.002	0.07
AMW1	0.26	0.006	0.01	0.28	0.03	0.03	0.002	0.06
AMW2	0.27	0.006	0.01	0.29	0.03	0.02	0.002	0.06
FSS1	0.28	0.006	0.01	0.3	0.04	0.03	0.002	0.06
FSS2	0.27	0.006	0.01	0.29	0.03	0.03	0.002	0.06

Table SM10. Total cancer risk of trace metals

CHILD					ADULT			
	RISKIng	RISKInh	RISKDerm	Total Cancer Risk	RISKIng	RISKInh	RISKDerm	Total Cancer Risk
APS1	7.63E-06	8.11E-07	1.04E-07	8.54E-06	2.10E-06	1.86E-06	1.02E-08	3.98E-06
APS2	1.40E-05	1.30E-06	1.66E-07	1.54E-05	3.85E-06	2.98E-06	1.63E-08	6.84E-06
PTF1	9.16E-06	9.32E-07	1.14E-07	1.02E-05	2.53E-06	2.14E-06	1.12E-08	4.68E-06
PTF2	8.40E-06	8.71E-07	1.09E-07	9.38E-06	2.31E-06	2.00E-06	1.07E-08	4.33E-06
SWD1	1.12E-05	1.08E-06	1.37E-07	1.24E-05	3.08E-06	2.49E-06	1.35E-08	5.58E-06
SWD2	1.02E-05	1.01E-06	1.26E-07	1.13E-05	2.80E-06	2.32E-06	1.24E-08	5.13E-06
AMW1	9.28E-06	9.39E-07	1.17E-07	1.03E-05	2.56E-06	2.16E-06	1.15E-08	4.73E-06
AMW2	1.02E-05	1.01E-06	1.27E-07	1.14E-05	2.82E-06	2.32E-06	1.25E-08	5.16E-06
FSS1	1.02E-05	1.01E-06	1.27E-07	1.13E-05	2.81E-06	2.32E-06	1.24E-08	5.14E-06
FSS2	9.74E-06	9.75E-07	1.22E-07	1.08E-05	2.69E-06	2.24E-06	1.20E-08	4.94E-06

Table SM11. Contamination/pollution index and Enrichment factor of metals

Site	Depth	Contamination/pollution index							Enrichment factors						
		Cd	Pb	Cr	Ni	Cu	Zn	MPI	Cd	Pb	Cr	Ni	Cu	Mn	Zn
APS1	Top soil	3.73	0	0.08	0.01	0.64	0	3.73	163	0.21	1.37	0.07	8.44	0.26	0
	Sub soil	10.4	0.01	0.08	3.6	0.35	0.01	14	524	0.71	1.68	34.98	5.33	1.13	0.25
APS2	Top soil	4.04	0.02	0.12	0.37	0.7	0.01	4.04	117	0.8	1.44	2.04	6.09	0.52	0.17
	Sub soil	24	0.01	0.09	1.52	0.02	0.01	25.5	937	0.9	1.5	11.46	0.24	0.45	0.23
PTF1	Top soil	3.98	0.01	0.08	0.55	3.47	0.04	7.45	48.8	0.2	0.42	1.31	12.8	0.69	0.24
	Sub soil	4.25	0.05	0.05	0.76	1.51	0.03	5.76	32	0.6	0.17	1.1	3.42	0.24	0.14
PTFS2	Top soil	3.85	0.01	0.08	0.28	2.06	0.02	5.91	74	0.2	0.63	1.04	11.84	0.6	0.19
	Sub soil	7.33	0.03	0.07	2.18	0.93	0.01	7.33	96	0.6	0.37	5.52	3.67	0.36	0.07
SWD1	Top soil	3.94	0.01	0.1	0.32	1.38	0.01	5.32	59	0.3	0.62	0.94	6.2	0.37	0.12
	Sub soil	15.7	0.02	0.08	1.85	0.48	0.01	17.5	308	0.7	0.65	7.01	2.8	0.38	0.11
SWD2	Top soil	3.96	0.01	0.09	0.44	2.43	0.03	6.39	53.5	0.2	0.51	1.14	9.83	0.55	0.19
	Sub soil	9.96	0.03	0.07	1.3	0.99	0.01	11.3	109	0.6	0.3	2.74	3.25	0.28	0.06
AMW1	Top soil	3.9	0.01	0.09	0.36	2.24	0.02	6.15	61.9	0.2	0.56	1.1	10.66	0.57	0.19
	Sub soil	8.64	0.03	0.07	1.74	0.96	0.01	10.4	103	0.6	0.33	4	3.44	0.31	0.07
AMW2	Top soil	3.92	0.01	0.09	0.34	1.81	0.02	5.73	60.5	0.24	0.59	1.02	8.37	0.47	0.15
	Sub soil	12.2	0.03	0.07	1.8	0.72	0.01	14	180.3	0.6	0.45	5.14	3.2	0.34	0.08
FSS1	Top soil	3.94	0.01	0.09	0.39	2.12	0.02	6.06	56.7	0.2	0.55	1.08	9.15	0.51	0.17
	Sub soil	11.1	0.03	0.07	1.55	0.86	0.01	12.6	139	0.6	0.37	3.76	3.23	0.3	0.07
FSS2	Top soil	3.92	0.01	0.09	0.38	2.18	0.02	6.1	59.2	0.2	0.56	1.09	9.87	0.54	0.18
	Sub soil	9.85	0.03	0.07	1.65	0.91	0.01	11.5	120.5	0.6	0.35	3.89	3.33	0.31	0.07

Table SM12. Geoaccumulation index of metals

Site	Depth	Cd	Pb	Cr	Ni	Cu	Mn	Zn	Fe
APS1	Top soil	2.73	-9.16	-4.16	-8.51	-1.55	-6.55	-12.80	-4.62
	Sub soil	4.21	-7.57	-4.07	0.30	-2.41	-4.64	-6.85	-4.82
APS2	Top soil	2.84	-6.57	-3.49	-2.99	-1.42	-4.96	-6.60	-4.02
	Sub soil	5.42	-6.83	-3.87	-0.94	-6.49	-5.62	-6.57	-4.46
PTF1	Top soil	2.82	-7.57	-4.03	-2.39	0.89	-3.32	-4.82	-2.79
	Sub soil	2.92	-5.16	-4.64	-1.94	-0.31	-4.15	-4.93	-2.09

Site	Depth	Cd	Pb	Cr	Ni	Cu	Mn	Zn	Fe
PTFS2	Top soil	2.78	-8.16	-4.09	-3.37	0.13	-4.17	-5.81	-3.43
	Sub soil	3.70	-5.91	-4.33	-0.42	-1.01	-4.37	-6.70	-2.89
SWD1	Top soil	2.81	-7.16	-3.76	-3.17	-0.44	-4.51	-6.15	-3.08
	Sub soil	4.80	-6.30	-4.08	-0.66	-1.98	-4.87	-6.63	-3.47
SWD2	Top soil	2.82	-7.35	-3.89	-2.73	0.37	-3.79	-5.34	-2.93
	Sub soil	4.15	-5.62	-4.33	-1.16	-0.92	-4.46	-6.67	-2.62
AMW1	Top soil	2.80	-7.70	-3.99	-3.02	0.26	-3.97	-5.56	-3.16
	Sub soil	3.94	-5.75	-4.33	-0.74	-0.96	-4.42	-6.67	-2.75
AMW2	Top soil	2.80	-7.40	-3.87	-3.09	-0.05	-4.22	-5.82	-3.12
	Sub soil	4.43	-6.00	-4.20	-0.70	-1.38	-4.62	-6.65	-3.06
FSS1	Top soil	2.81	-7.37	-3.88	-2.90	0.18	-3.99	-5.56	-3.02
	Sub soil	4.30	-5.80	-4.27	-0.91	-1.13	-4.54	-6.67	-2.82
FSS2	Top soil	2.80	-7.53	-3.93	-2.96	0.22	-3.98	-5.56	-3.09
	Sub soil	4.13	-5.77	-4.30	-0.83	-1.05	-4.48	-6.66	-2.78

Table SM13. Contamination factor, degree of contamination and contamination level of metals

Site	Depth	Contamination factor (C _f)								Degree of Contamination (C _d)	Contamination level
		Cd	Pb	Cr	Ni	Cu	Co	Mn	Zn		
APS1	Top soil	9.93	0.01	0.08	0.00	0.51	0.00	0.02	0.00	10.56	Considerable
	Sub soil	27.77	0.04	0.09	1.85	0.28	0.00	0.06	0.01	30.10	High
APS2	Top soil	10.77	0.08	0.13	0.19	0.56	0.00	0.05	0.02	11.79	Considerable
	Sub soil	64.00	0.06	0.10	0.78	0.02	0.00	0.03	0.02	65.01	High
PTF1	Top soil	10.60	0.04	0.09	0.29	2.78	0.00	0.15	0.05	14.00	Considerable
	Sub soil	11.33	0.20	0.06	0.39	1.21	0.00	0.08	0.05	13.32	Considerable
PTFS2	Top soil	10.27	0.03	0.09	0.14	1.65	0.00	0.08	0.03	12.28	Considerable
	Sub soil	19.55	0.12	0.07	1.12	0.74	0.00	0.07	0.01	21.70	High
SWD1	Top soil	10.52	0.05	0.11	0.17	1.10	0.00	0.07	0.02	12.03	Considerable
	Sub soil	41.78	0.09	0.09	0.95	0.38	0.00	0.05	0.02	43.35	High
SWD2	Top soil	10.56	0.04	0.10	0.23	1.94	0.00	0.11	0.04	13.02	Considerable
	Sub soil	26.55	0.15	0.07	0.67	0.79	0.00	0.07	0.01	28.32	High
AMW1	Top soil	10.41	0.03	0.09	0.19	1.79	0.00	0.10	0.03	12.65	Considerable
	Sub soil	23.05	0.13	0.07	0.90	0.77	0.00	0.07	0.01	25.01	High
AMW2	Top soil	10.46	0.04	0.10	0.18	1.45	0.00	0.08	0.03	12.34	Considerable
	Sub soil	32.41	0.11	0.08	0.92	0.57	0.00	0.06	0.01	34.18	High
FSS1	Top soil	10.51	0.04	0.10	0.20	1.69	0.00	0.09	0.03	12.68	Considerable
	Sub soil	29.48	0.13	0.08	0.80	0.68	0.00	0.06	0.01	31.25	High
FSS2	Top soil	10.46	0.04	0.10	0.19	1.74	0.00	0.10	0.03	12.66	Considerable
	Sub soil	26.27	0.13	0.08	0.85	0.73	0.00	0.07	0.01	28.13	High

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