Appendix A: Supplementary Material

Tempo-spatial variability and health risks of PM2.5 and associated metal(loid)s in Greater Cairo, Egypt

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Table A1. Values of the terms used to calculate the intake doses of PM2.5 associated metal(loid)s through ingestion, dermal and inhalation routes of exposure (Eq. 1, 2 and 3).

Term	Unit	Value		Reference
		Children	Adults	
IngR	mg day^{-1}	200	100	(USEPA, 1989, Megido et al., 2017)
EF	days $year^{-1}$	350	350	(USEPA, 2014, Roy et al., 2019)
ED	years	6	20	(USEPA, 2014)
CF	kg mg^{-1}	0.000001	0.000001	(USEPA, 1989, Roy et al., 2019)
BW	kg	15	80	(USEPA, 2014)
$AT_{id\ (}$non-carcinogenic)	days	2190	7300	(USEPA, 1989, Sah et al., 2019)
$AT_{id\ (}$carcinogenic)	days	25550	25550	(USEPA, 1989, Sah et al., 2019)
SA	cm^2	2800	5700	(USEPA, 2004, Megido et al., 2017)
AF	mg cm^{-2}	0.2	0.07	(USEPA, 2004, Megido et al., 2017)
ET	hr day^{-1}	24	24	(USEPA, 2009, Roy et al., 2019)
$AT_{n\ (}$non-carcinogenic)	hr	52560	175200	(USEPA, 2009, Sah et al., 2019)
$AT_{n\ (}$carcinogenic)	hr	613200	613200	(USEPA, 2009, Sah et al., 2019)

Table A2. Values of the terms used to calculate the intake doses of PM2.5 associated metal(loid)s through ingestion, dermal and inhalation routes of exposure (Eq. 1, 2 and 3), the non-carcinogenic hazard quotients (Eq. 4, 5 and 6) and the carcinogenic risks (Eq. 7, 8, 9 and 10). NA= Not Applicable. NV = Not Available. 95% UCL is the 95% upper confidence limit (calculated by Minitab 17 statistical software) of the annual average concentrations of PM2.5 metalloids in Dokki (urban) and Al-Tebbin (industrial) areas.

Term	C (Ingestion & Dermal)		C (Inhalation)		ABS	GIABS	SFo	IUR	RFDo	RFCi
	Dokki 95% UCL ($mg\ kg^{-1}$)	Al-Tebbin 95% UCL ($mg\ kg^{-1}$)	Dokki 95% UCL ($\mu g\ m^{-3}$)	Al-Tebbin 95% UCL ($\mu g\ m^{-3}$)	(unitless)	(unitless)	$((mg\ kg^{-1}\ day^{-1})^{-1})$	$((\mu g\ m^{-3})^{-1})$	($mg\ kg^{-1}\ day^{-1}$)	($mg\ m^{-3}$)
Al	67189	145086	1.997	4.731	0.01	1	NV	NV	1	0.005
V	486	154.9	0.0131	0.00847	0.01	0.026	NV	NV	0.005	0.0001
Cr	525	203.8	0.0127	0.00823	NA	NA	NA	NA	NA	NA
Cr(VI)	75	29.11429	0.0018	0.00118	0.01	0.025	0.5	0.084	0.003	0.0001
Mn	663	1033.3	0.0199	0.04648	0.01	0.04	NV	NV	0.024	0.00005
Fe	28229	18147	0.8742	0.9516	0.01	1	NV	NV	0.7	NV
Co	12.5	28.46	0.0004	0.00112	0.01	1	NV	0.009	0.0003	0.000006
Ni	458	128.6	0.0121	0.00581	0.01	0.04	0.91	0.00024	0.011	0.000014
Cu	1778	1068	0.0591	0.04077	0.01	1	NV	NV	0.04	0.0402
Zn	162968	150659	4.759	8.02	0.01	1	NV	NV	0.3	0.3
As	270	54.08	0.0081	0.00212	0.03	1	1.5	0.0043	0.0003	0.000015
Cd	141	62.04	0.0044	0.00331	0.001	0.025	0.64	0.0018	0.001	0.00001
Pb	4194	6490	0.0996	0.2898	0.01	1	0.28	0.000012	0.0035	0.00352
Reference	This Work	This Work	This Work	This Work	*	*	**	*	*	***

* (Megido et al., 2017, USEPA, 2019)

** (Roy et al., 2019, USEPA, 2019, RAIS, 2020)

*** (Megido et al., 2017, Roy et al., 2019, USEPA, 2019)

Table A3. Annual and seasonal PM2.5 concentrations ($\mu g\ m^{-3}$) in Dokki urban and Al-Tebbin industrial areas of Greater Cairo, Egypt, in comparison to WHO annual and 24 h average guideline values. NA = Not Applicable.

	Dokki					Al-Tebbin					WHO	WHO
	Mean	SD	Max	Min	Median	Mean	SD	Max	Min	Median		
Spring (March – May)	41.8	31.2	165	19.9	33.7	57.6	47.7	176	19.6	41.2	NA	NA
Summer (June – August)	30.4	11.0	46.6	15.7	28.4	79.8	48	159	17.9	64.7	NA	NA
Autumn (September – November)	24.3	8.08	39.4	8.93	23.5	55.7	27.1	117	26.6	48.9	NA	NA
Winter (December – February)	52.4	30.9	134	16.2	46.4	30	9.94	50.2	15.4	28.6	NA	NA
Annual	37.2	25.3	165	8.93	30.9	56.4	40	176	15.4	41.9	10	5
24 hrs	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	25	10
Reference	This Work					This Work					(WHO, 2006)	(WHO, 2021)

Table A4. Statistical significance of the differences between the seasonal and annual concentrations of PM2.5 and associated metal(loid)s measured in Greater Cairo urban (Dokki) vs Grater Cairo industrial (Al-Tebbin) sites. Statistical significance is represented as p-values (calculated by Minitab 17 statistical package); p-values <0.05 were considered significant and are shown in bold and highlighted in grey. NA = Not Applicable (data not available).

	Spring	Summer	Autumn	Winter	Annual
PM2.5	0.36	**<0.01**	**<0.01**	**0.01**	**<0.01**
Al	**<0.01**	**<0.01**	**0.03**	**<0.01**	**<0.01**
V	0.53	**<0.01**	NA	NA	NA
Cr	NA	0.26	**<0.01**	**<0.01**	NA
Mn	**0.01**	**0.03**	**<0.01**	**0.02**	**<0.01**
Fe	**0.01**	**<0.01**	**<0.01**	0.11	0.64
Co	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Ni	**<0.01**	**<0.01**	**0.02**	**<0.01**	**<0.01**
Cu	0.13	**<0.01**	0.07	**<0.01**	**<0.01**
Zn	**<0.01**	**<0.01**	0.74	**<0.01**	0.21
As	**<0.01**	**<0.01**	0.87	**<0.01**	**<0.01**
Cd	**0.01**	0.41	0.54	**<0.01**	0.15
Pb	0.67	**<0.01**	0.19	0.6	**<0.01**

Table A5. Statistical significance of the differences between the seasonal concentrations of PM2.5 ($\mu g\ m^{-3}$) in Greater Cairo urban and Industrial sites (Dokki and Al-Tebbin). Statistical significance is represented as p-values (calculated by Minitab 17 statistical package); p-values <0.05 were considered significant and are shown in bold and highlighted in grey.

	Spring-Summer	Spring-Autumn	Spring-Winter	Summer-Autumn	Summer-Winter	Autumn-Winter
Dokki	0.13	**0.02**	0.24	0.08	**0.01**	**<0.01**
Al-Tebbin	0.3	0.92	0.11	0.17	**<0.01**	**0.02**

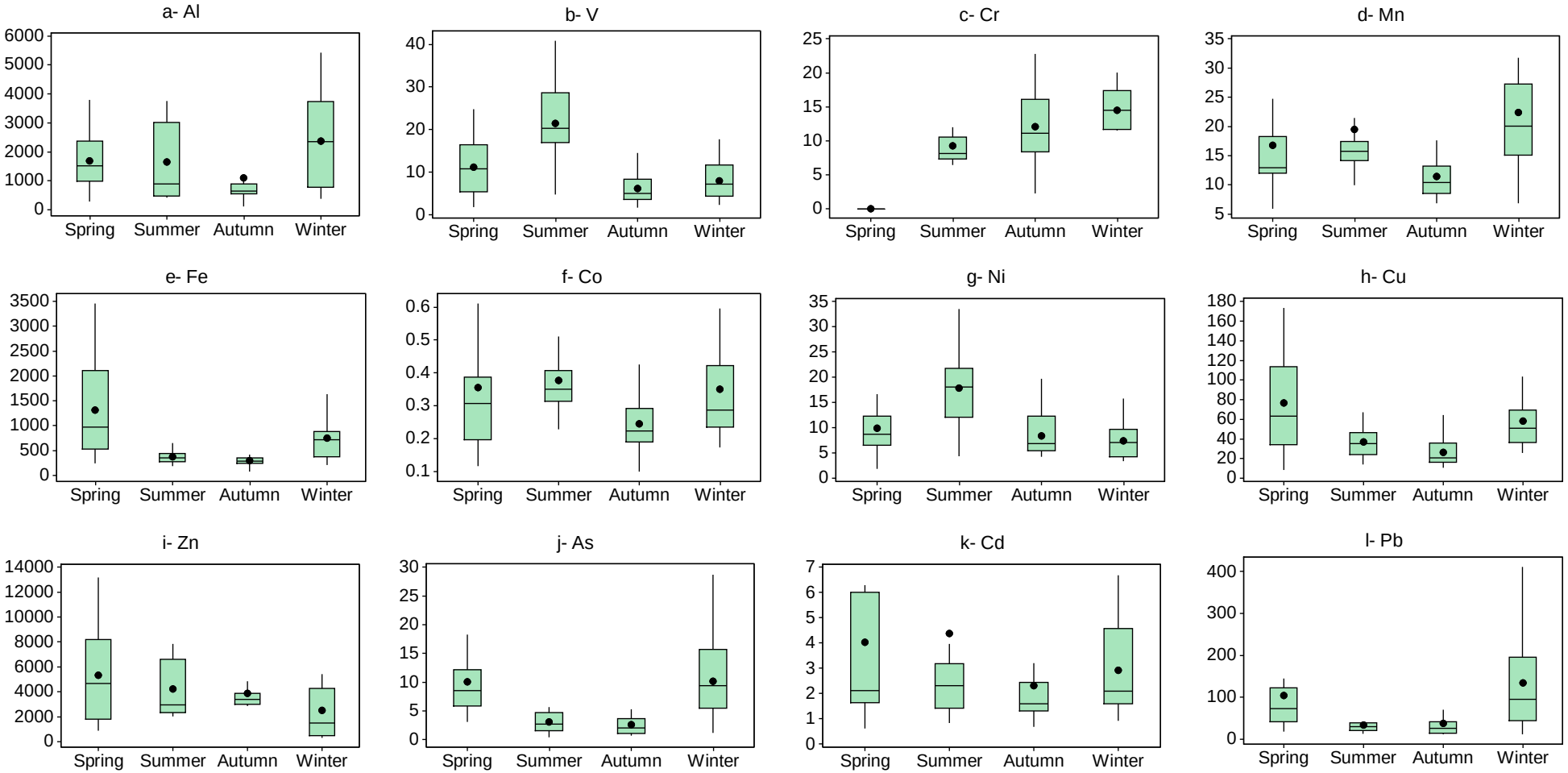

Fig. A1. Seasonal concentrations (ng m^{-3}) of 12 PM2.5 associated metal(loid)s in Dokki urban district, Greater Cairo, Egypt, represented as box and whisker plots. The boxes represent the lower boundaries of the second and third quartile, the whiskers extend to the furthest data point within 1.5 box heights. Means are shown as black circles, medians as horizontal lines and outliers are not displayed. Statistical summary of the displayed data can be found in Table A4 (Appendix A: Supplementary Material).

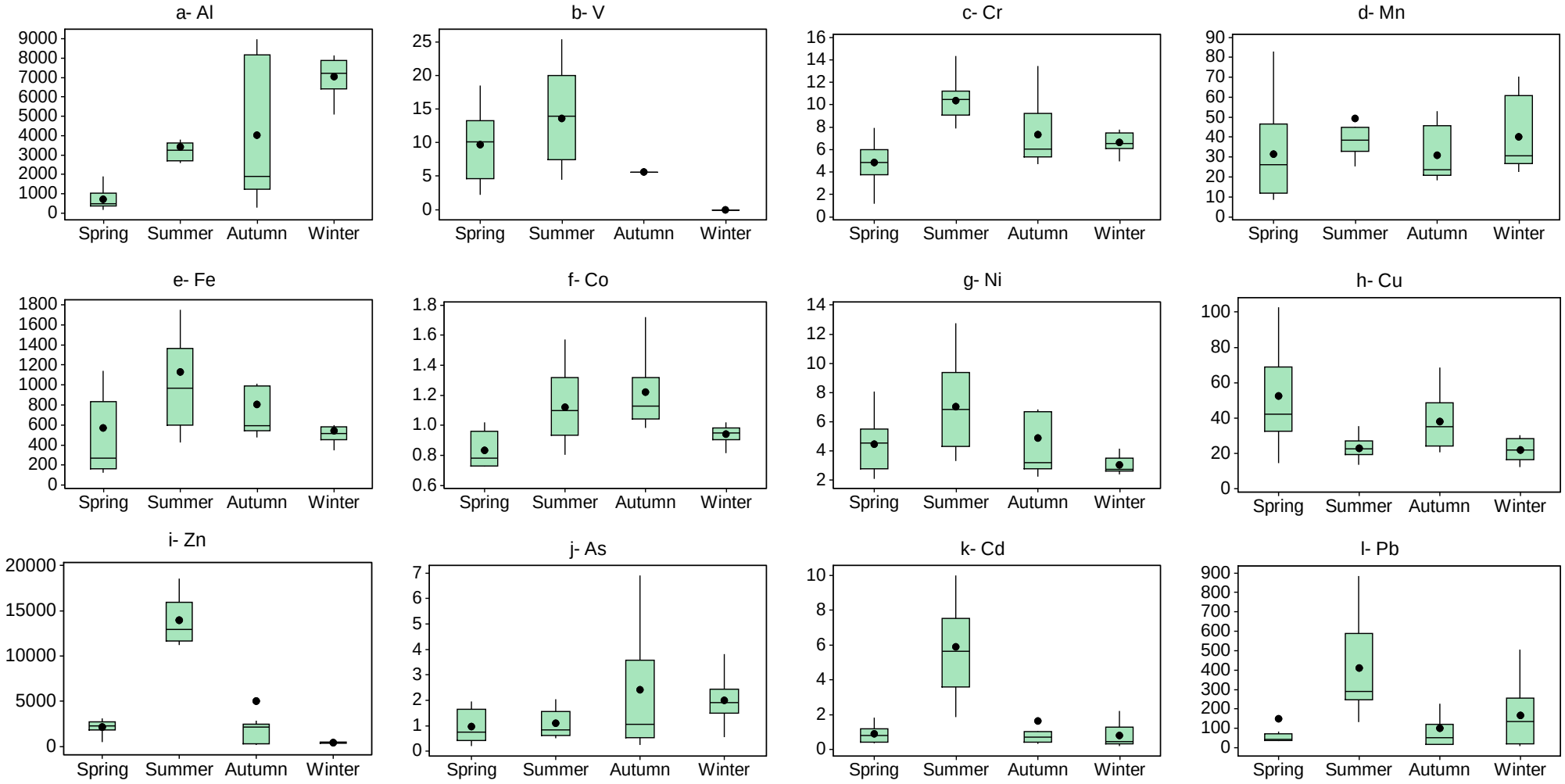

Fig. A2. Seasonal concentrations (ng m^{-3}) of 12 PM2.5 associated metal(loid)s in Al-Tebbin industrial district, Greater Cairo, Egypt, represented as box and whisker plots. The boxes represent the lower boundaries of the second and third quartile, the whiskers extend to the furthest data point within 1.5 box heights. Means are shown as black circles, medians as horizontal lines and outliers are not displayed. Full data set can be found in Table A4 (Appendix A: Supplementary Material).

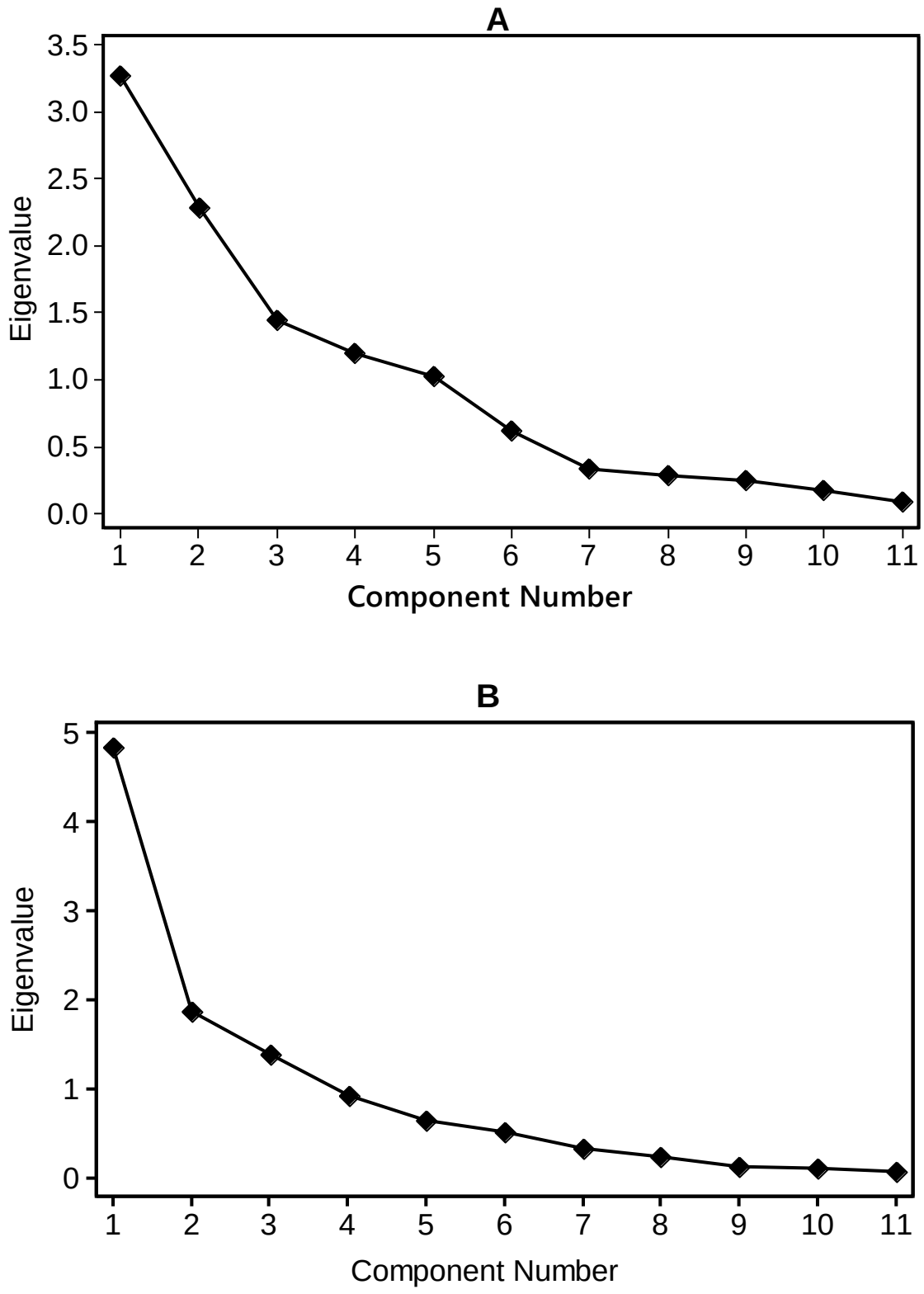

Fig. A3. Scree plots of the principle component analysis performed (by Mintiab 17 software package) on the ambient air concentrations (ng m^{-3}) of PM2.5 associated Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Pb in A- Dokki (urban) and B- Al-Tebbin (industrial) districts.

Table A6. Cairo Urban (Dokki area) non-carcinogenic hazard quotients (HQ), hazard indices (HI) and carcinogenic risks (CR) for all elements and exposure routes (individually and combined). Relative contributions (%) of each exposure route (for individual elements and for all elements combined) are also displayed for both non-carcinogenic and carcinogenic risks. Non-carcinogenic HQs or HIs >1 and carcinogenic risks (CR) > $1x10^{-4}$ are displayed in bold and highlighted in grey. NA = Not Applicable.

Element		Al	V	Cr(VI)	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Pb	Total
Non-Carcinogenic Risks														
Ingestion (HQ/HI)	Children	0.859	**1.243**	0.32	0.353	0.516	0.532	0.532	0.568	**6.945**	**11.51**	**1.799**	**15.32**	**40.49**
	Adults	0.081	0.117	0.03	0.033	0.048	0.05	0.05	0.053	0.651	**1.079**	0.169	**1.436**	**3.796**
Dermal (HQ/HI)	Children	0.024	**1.339**	0.358	0.247	0.014	0.015	0.373	0.016	0.194	0.967	0.201	0.429	**4.177**
	Adults	0.003	0.179	0.048	0.033	0.002	0.002	0.05	0.002	0.026	0.129	0.027	0.057	0.558
Inhalation (HQ/HI)	Children	0.383	0.125	0.017	0.381	NA	0.06	0.827	0.001	0.015	0.518	0.419	0.027	**2.775**
	Adults	0.383	0.125	0.017	0.381	NA	0.06	0.827	0.001	0.015	0.518	0.419	0.027	**2.775**
Total (HI)	Children	**1.266**	**2.707**	0.695	0.982	0.530	0.606	**1.732**	0.586	**7.155**	**12.99**	**2.420**	**15.78**	**47.45**
	Adults	0.467	0.421	0.095	0.447	0.05	0.112	0.926	0.057	0.692	**1.726**	0.615	**1.521**	**7.129**
Ingestion Contribution (%)	Children	67.85	45.92	45.99	35.97	97.28	87.69	30.74	97.04	97.07	88.57	74.35	97.11	85.35
	Adults	17.25	27.7	31.47	7.4	96.16	44.66	5.39	93.78	94.05	62.5	27.43	94.45	53.25
Dermal Contribution (%)	Children	1.9	49.45	51.5	25.18	2.72	2.46	21.52	2.72	2.72	7.44	8.33	2.72	8.8
	Adults	0.69	42.5	50.22	7.38	3.84	1.78	5.37	3.74	3.75	7.48	4.38	3.77	7.83
Inhalation Contribution (%)	Children	30.25	4.63	2.51	38.84	NA	9.86	47.75	0.24	0.21	3.99	17.33	0.17	5.85
	Adults	82.06	29.80	18.31	85.22	NA	53.56	89.24	2.48	2.2	30.02	68.19	1.78	38.92
Element Total Contribution (%)	Children	2.67	5.71	1.47	2.07	1.12	1.28	3.65	1.23	15.08	27.38	5.1	33.25	100
	Adults	6.55	5.90	1.34	6.28	0.71	1.57	12.99	0.80	9.71	24.21	8.62	21.33	100
Carcinogenic Risks														
Ingestion (CR)	Children	NA	NA	4.11E-05	NA	NA	NA	**4.57E-04**	NA	NA	**4.44E-04**	9.87E-05	**1.29E-03**	**2.33E-03**
	Adults	NA	NA	1.28E-05	NA	NA	NA	**1.43E-04**	NA	NA	**1.39E-04**	3.08E-05	**4.02E-04**	**7.27E-04**

Dermal (CR)	Children	NA	NA	4.61E-05	NA	NA	NA	**3.20E-04**	NA	NA	3.73E-05	1.11E-05	3.60E-05	**4.50E-04**
	Adults	NA	NA	2.05E-05	NA	NA	NA	**1.42E-04**	NA	NA	1.66E-05	4.92E-06	1.60E-05	**2.00E-04**
Inhalation (CR)	Children	NA	NA	1.26E-05	NA	NA	2.77E-07	2.38E-07	NA	NA	2.87E-06	6.47E-07	9.82E-08	1.67E-05
	Adults	NA	NA	4.19E-05	NA	NA	9.22E-07	7.94E-07	NA	NA	9.55E-06	2.16E-06	3.27E-07	5.56E-05
Total (CR)	Children	NA	NA	9.97E-05	NA	NA	2.77E-07	**7.77E-04**	NA	NA	**4.84E-04**	**1.10E-04**	**1.32E-03**	**2.79E-03**
	Adults	NA	NA	7.52E-05	NA	NA	9.22E-07	**2.86E-04**	NA	NA	**1.65E-04**	3.79E-05	**4.19E-04**	**9.83E-04**
Ingestion Contribution (%)	Children	0.00	0.00	41.23	0.00	0.00	0.00	58.81	0.00	0.00	91.70	89.40	97.27	83.29
	Adults	0.00	0.00	17.08	0.00	0.00	0.00	49.92	0.00	0.00	84.14	81.33	96.09	73.96
Dermal Contribution (%)	Children	0.00	0.00	46.17	0.00	0.00	0.00	41.16	0.00	0.00	7.70	10.01	2.72	16.11
	Adults	0.00	0.00	27.26	0.00	0.00	0.00	49.80	0.00	0.00	10.07	12.98	3.83	20.38
Inhalation Contribution (%)	Children	0.00	0.00	12.60	0.00	0.00	100	0.03	0.00	0.00	0.59	0.59	0.01	0.60
	Adults	0.00	0.00	55.66	0.00	0.00	100	0.28	0.00	0.00	5.79	5.69	0.08	5.66
Element Contribution (%)	Children	0.00	0.00	3.57	0.00	0.00	0.01	27.79	0.00	0.00	17.32	3.95	47.35	100
	Adults	0.00	0.00	7.65	0.00	0.00	0.09	29.07	0.00	0.00	16.76	3.86	42.56	100

Table A7. Cairo Industrial (Al-Tebbin area) non-carcinogenic hazard quotients (HQ), hazard indices (HI) and carcinogenic risks (CR) for all elements and exposure routes (individually and combined). Relative contributions (%) of each exposure route (for individual elements and for all elements combined) are also displayed for both non-carcinogenic and carcinogenic risks. Non-carcinogenic HQs or HIs >1 and carcinogenic risks (CR) > $1x10^{-4}$ are displayed in bold. NA = Not Applicable.

Element		Al	V	Cr(VI)	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Pb	Total
Non-Carcinogenic Risks														
Ingestion (HQ/HI)	Children	**1.855**	0.396	0.124	0.55	0.331	**1.213**	0.149	0.341	**6.421**	**2.3**	0.793	**23.71**	**38.19**
	Adults	0.174	0.037	0.012	0.052	0.031	0.114	0.014	0.032	0.602	0.216	0.074	**2.223**	**3.58**
Dermal (HQ/HI)	Children	0.052	0.427	0.139	0.385	0.009	0.034	0.105	0.01	0.18	0.194	0.089	0.664	**2.286**
	Adults	0.007	0.057	0.019	0.051	0.001	0.005	0.014	0.001	0.024	0.026	0.012	0.089	0.305
Inhalation (HQ/HI)	Children	0.907	0.081	0.011	0.891	NA	0.179	0.398	0.001	0.026	0.136	0.318	0.079	**3.028**
	Adults	0.907	0.081	0.011	0.891	NA	0.179	0.398	0.001	0.026	0.136	0.318	0.079	**3.028**
Total (HI)	Children	**2.814**	0.904	0.274	**1.827**	0.341	**1.426**	0.652	0.352	**6.626**	**2.63**	**1.2**	**24.45**	**43.5**
	Adults	**1.088**	0.175	0.041	0.994	0.032	0.297	0.426	0.034	0.652	0.378	0.404	**2.39**	**6.913**
Ingestion Contribution (%)	Children	65.91	43.82	45.23	30.13	97.28	85.06	22.91	97.01	96.9	87.5	66.12	96.96	87.78
	Adults	15.98	21.18	28.05	5.19	96.16	38.23	3.29	93.43	92.38	57.2	18.41	92.99	51.79
Dermal Contribution (%)	Children	1.85	47.19	50.66	21.09	2.72	2.38	16.04	2.72	2.71	7.35	7.41	2.71	5.26
	Adults	0.64	32.50	44.76	5.18	3.84	1.53	3.28	3.73	3.69	6.85	2.94	3.71	4.42
Inhalation Contribution (%)	Children	32.24	8.99	4.11	48.79	NA	12.56	61.05	0.28	0.39	5.15	26.47	0.32	6.96
	Adults	83.38	46.32	27.19	89.63	NA	60.24	93.43	2.84	3.93	35.95	78.65	3.3	43.79
Element Total Contribution (%)	Children	6.47	2.08	0.63	4.2	0.78	3.28	1.5	0.81	15.23	6.06	2.76	56.21	100
	Adults	15.74	2.54	0.6	14.39	0.47	4.3	6.17	0.5	9.43	5.46	5.84	34.58	100
Carcinogenic Risks														
Ingestion (CR)	Children	NA	NA	1.60E-05	NA	NA	NA	**1.28E-04**	NA	NA	8.89E-05	4.35E-05	**1.99E-03**	**2.27E-03**
	Adults	NA	NA	4.99E-06	NA	NA	NA	4.01E-05	NA	NA	2.78E-05	1.36E-05	**6.22E-04**	**7.09E-04**

Dermal (CR)	Children	NA	NA	1.79E-05	NA	NA	NA	8.98E-05	NA	NA	7.47E-06	4.87E-06	5.58E-05	**1.76E-04**
	Adults	NA	NA	7.96E-06	NA	NA	NA	4.00E-05	NA	NA	3.33E-06	2.17E-06	2.48E-05	7.83E-05
Inhalation (CR)	Children	NA	NA	8.12E-06	NA	NA	8.29E-07	1.15E-07	NA	NA	7.51E-07	4.90E-07	2.86E-07	1.06E-05
	Adults	NA	NA	2.71E-05	NA	NA	2.76E-06	3.82E-07	NA	NA	2.50E-06	1.63E-06	9.53E-07	3.53E-05
Total (CR)	Children	NA	NA	4.19E-05	NA	NA	8.29E-07	**2.18E-04**	NA	NA	9.71E-05	4.89E-05	**2.05E-03**	**2.45E-03**
	Adults	NA	NA	4.00E-05	NA	NA	2.76E-06	8.04E-05	NA	NA	3.36E-05	1.74E-05	**6.48E-04**	**8.22E-04**
Ingestion Contribution (%)	Children	0.00	0.00	38.04	0.00	0.00	0.00	58.79	0.00	0.00	91.54	89.03	97.26	92.41
	Adults	0.00	0.00	12.46	0.00	0.00	0.00	49.82	0.00	0.00	82.66	78.14	96.02	86.19
Dermal Contribution (%)	Children	0.00	0.00	42.60	0.00	0.00	0.00	41.15	0.00	0.00	7.69	9.97	2.72	7.16
	Adults	0.00	0.00	19.89	0.00	0.00	0.00	49.70	0.00	0.00	9.89	12.47	3.83	9.52
Inhalation Contribution (%)	Children	0.00	0.00	19.36	0.00	0.00	100	0.05	0.00	0.00	0.77	1.00	0.01	0.43
	Adults	0.00	0.00	67.66	0.00	0.00	100	0.48	0.00	0.00	7.45	9.39	0.15	4.29
Element Contribution (%)	Children	0.00	0.00	1.71	0.00	0.00	0.03	8.89	0.00	0.00	3.96	1.99	83.42	100
	Adults	0.00	0.00	4.87	0.00	0.00	0.34	9.78	0.00	0.00	4.09	2.12	78.81	100

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