SARS-CoV-2 EPIDEMIC FIRST WAVE: THE IMPACT OF PARTIAL AND COMPLETE LOCKDOWNS ON ROAD-DEPOSITED SEDIMENTS IN KUWAIT

ALSANAD, A, – ALSHAWAF, M.*

College of Life Sciences, Environmental Technology Management, Kuwait University, P.O. Box 5969, Safat 13060, Kuwait

*Corresponding author
e-mail: abdullah.alsanad@ku.edu.kw; phone: +965-2463-3230

(Received 8th Aug 2022; accepted 17th Nov 2022)

Abstract. This research aims to find the impact of the nationwide partial and complete lockdowns on the environmental quality of Kuwait. This objective was accomplished by collecting roadside deposited sediments (n=54) at three periods during the first wave of the SARS-CoV-2 epidemic (complete-lockdown, partial-lockdown, and re-opening) from different locations in Kuwait and then analyzing them via ICP-AES for the presence of heavy metals and later applying various pollution indices. Extensive analysis of 162 subsamples showed that virtually all the minimum values were associated with the complete lockdown period (9 out of 10 elements). Pearson's correlation coefficients indicate that all elements are positively correlated except for Cu-Cd, Cu-Cr, and Co-V, suggesting that the sediments share a common source. Except for cadmium and copper, almost all sediments showed low ecological risk potential (Eri < 40). The lowest risk index was during the complete lockdown (RI=162.2). The full lockdown period had marginally lower geo-accumulation indices and classes than the partial lockdown and re-opening periods. The improvement in sediment quality between the different periods was minimal due to low levels of commitment in the governmental curfew leave permissions, the continuity of Kuwait municipality manual and mechanical road cleanup processes during lockdowns, and the associated energy consumption with emissions resulting from extended indoor stay.
Keywords: *road dust, enrichment factor, risk index, contamination factor, sediments*

Introduction

Due to the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), many countries imposed partial and complete lockdowns (Hoertel et al., 2020). Lockdowns were one of the measures taken by the governments to contain the rise of covid-19 cases and deaths (Moser and Yared, 2021). They ranged from neighborhood to nationwide and long-term to short-term (Ren, 2020). This has led to the closure of many commercial and industrial facilities (Haleem et al., 2020), and fewer people were going to work which resulted in fewer vehicles on the road whether buses or passenger cars (Tirachini and Cats, 2020). Many of the above-listed activities rely on fossil fuels, either directly or indirectly, releasing harmful particulates into the air. The study of deposited sediments is vital in examining the environmental quality of a region or an area (Duzgoren-Aydin et al., 2006). Scientists have examined dust sediments in general and road-deposited sediments specifically for decades (Loganathan et al., 2013). Roads are sinks for urban sediments (Zhang and Hao, 2009; Hanfi et al., 2020) and harbour potentially toxic heavy metals' such as cadmium, cobalt, and zinc in the composition of these road deposited sediments (Wei et al., 2015; Lanzerstorfer, 2018; Wang et al., 2020). These heavy metals, among others, are in excess and are harmful to human and environmental health (Wei et al., 2015). Another reason for studying urban road sediments is to know how commercial or industrial activities

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

influence environmental conditions (Zhao et al., 2011; Quiñonez-Plaza et al., 2017; Alsanad and Alolayan, 2020).

The deposited sediments come from natural processes such as dust storms, soil erosion, wildfires (Men et al., 2018; Jeong et al., 2021), and human-induced processes such as construction, mining operations, and fuel-burning (Niyogi, 2011). Fossil fuel burning occurs mainly in power generation plants and vehicles (Yuen, 2012). The sources are sometimes referred to as extrinsic and intrinsic sources (*Table 1*). Extrinsic sources are environmental sources deriving from eroded soil, tree leaves, dry atmospheric deposition, and wet atmospheric deposition. Intrinsic sources are human-related and are not limited to industrial processes only. They also include asphalt wear, brakes linings, vehicular frames, tire wear, road fences, road railings, pavement paint markings, deicing agents, pesticides, herbicides, and vehicular exhaust emissions (Zhao et al., 2011; Loganathan et al., 2013; Kim et al., 2019). Among the above-mentioned sources, industrial processes, pavement and tire wear, and vehicular exhaust emissions are the major contributors (Zhao et al., 2011; Jeong et al., 2021). Hong et al. (2020) assessed the relative contribution of five prominent heavy metals quantitatively and found that tyre wear was the most significant contributor to the road-deposited sediment mass, whereas the smallest contributor was the brake linings. Most Cu, Pb, and Zn were traced to brake linings, tire wear, and urban soil, while most Cr and Ni came from gasoline vehicle exhaust. The differentiation factors to consider when studying road deposited sediments include the vehicle types (i.e. passenger car, bus, motorcycle, tricar, bicycle, and heavy-duty trucks), fuel type (i.e., gasoline, diesel, and alternative fuels such as electricity), surface type (i.e., asphalt, concrete, and flexible), tire type (i.e., studded/studless winter tires, summer tires, and all-season tires), and road classification (i.e., highway and local road) (Loganathan et al., 2013; Kim et al., 2016; Wang et al., 2020; Hong et al., 2020; Alves et al., 2020). Heavy metals tend to concentrate in soils and road deposited sediments of industrial areas compared to residential and commercial areas (Zhao et al., 2011; Wang et al., 2020). Areas with passenger car traffic usually have high Cu and Pb levels, and sediments are primarily fine, whereas bus dense areas have high levels of Cu, and the sediments are mostly coarse. Areas with truck traffic have high levels of Ni and Zn. The slope gradient of the road is also a contributing factor as it influences the driving styles such as acceleration and braking. These actions eventually change the amounts of heavy metals in the road sediments and the size of particles (gentle slope/fine and steep slope/coarse) (Wang et al., 2020). Due to highways' relatively high traffic, impermeability, and speed limits, they are associated with significantly higher levels of polluted road deposited sediments per unit length (Kim et al., 2016).

The partial and complete lockdown hours and dates were part of Kuwait's back-to-normal life phases. The phases' dates were constantly changing, and the periods were extended frequently depending on the evaluation of the disease conditions. Each phase was initially three weeks long, but they were much longer; phase 5 was delayed for about 14 months. The updates were conveyed through the Center for Government Communication (CGC) Instagram and Twitter feeds, the official government communication channels. Phase 1 started at the end of May 2020 and involved a statewide partial lockdown from 6 pm to 6 am and a complete zonal lockdown on selected cities. The activities allowed during the first phases were limited and expanded as time progressed. Phase 2 was initially at the end of June 2020 and involved a slightly shorter partial Lockdown (9 pm-6 am) and a complete zonal lockdown (if necessary). The lockdown was lifted for phases 3 and above. The complete phase dates, lockdown status, and activities allowed are shown in *Table 2*. The objectives of this research are, first, to find the impact of the nationwide partial and

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

complete lockdowns on the environmental quality of Kuwait. Second, compare the impacts of the different governmental lockdown measures on the sediments' quality. These were accomplished by collecting roadside deposited sediments at different time intervals during the COVID-19 pandemic from different locations in Kuwait and then analyzing them for the presence of heavy metals and applying various pollution indices.

Table 1. *Extrinsic and Intrinsic Sources of Road-deposited sediments*

	Natural	Vehicle-Related	Road-Related	Other
Intrinsic		Traffic [1,5, 7, 10] Exhaust emissions [1,2,3, 8] Tire wear [2,3] Tire type [11] Brake shoes and linings [3,4,8] Body frame [3,4]	Asphalt wear [2,3] Concrete wear [3] Road rails [3,4] Road fences [3,4] Road Slope [9] Deicing salts [3] Surface paint markings [3,4] Road classification [12]	Industrial processes [1,2,5] Industrial spills [1] Pesticides [3] Herbicides [3] Building materials [7]
Extrinsic	Soil erosion [1,4, 10] Dust storms [6] Dry atmospheric deposition [1, 4] Wet atmospheric deposition [4] Leaf fall [4] Road Aggregates [8] Vegetation [10]			

[1] Jeong et al., 2021, [2] Zhao et al., 2011, [3] Loganathan et al., 2013, [4] Kim et al., 2019, [5] Zhang and Hao, 2009, [6] Men et al., 2018, [7] Quiñonez-Plaza et al., 2017, [8] Hong et al., 2020, [9] Wang et al., 2020, [10] Gelhardt et al., 2021, [11] Alves et al., 2020, [12] Kim et al., 2016

Table 2. *Kuwait's Official Initial Back-to-Normal Life Phases with tentative dates. Source*

Phases	Dates	Lockdown Status	Activities Allowed During non-lockdown hours	Activities Exempted from Lockdown (Source: Kuwait Municipality www.baladia.gov.kw)
Phase 1	31/5/2020	Partial Lockdown 6pm-6am, Complete Zonal Lockdown (Mahboula, Jaleeb Alshoyoukh, Farwaniya, Khaitan, Hawally, and Maidan Hawally)	Industrial Activities, worship places, restaurant delivery and drive-thru, gas stations, clinics, and car mechanics	Industrial facilities (petrochemicals, food supplies, gas manufacturers, plastic, and paper) Commercial facilities (Ration and food supplies, money exchange, opticians, laundry, maintenance shops, pharmacies, home improvement, fodder, and auto repair)
Phase 2	21/6/2020	Partial Lockdown 9pm-6am Full Zonal Lockdown (when needed)	The above-mentioned activities plus workplaces (<30% capacity), Construction, banks, retail stores and malls, and parks	
Phase 3	12/7/2020	No Lockdown Full Zonal Lockdown (when needed)	The activities mentioned above plus workplaces (<50% capacity), hotels and resorts, taxis (1 passenger only), and Friday prayers	
Phase 4	2/8/2020	No Lockdown	The above-mentioned activities plus workplaces (>50% capacity), restaurants (dine-in), and public transportation	
Phase 5	23/8/2020	No Lockdown	Public gatherings, weddings, graduation ceremonies, sporting events, conferences, and cinemas	

Source: State of Kuwait (2022)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

Materials and Methods

Samples collection and locations

The samples were collected according to Charlesworth et al. (2003) and Alsanad and Alolayan (2020). Due to the nature of this research and the lockdown period it was conducted, eighteen different university students and faculty were assigned as collectors. The collectors were given detailed instructions to ensure the collection of representative samples. They were instructed on how to collect the samples in front of their houses, store them to avoid sample contamination, tag them, and provide the location coordinates. The collectors were instructed to use pre-washed and dry brooms to collect the samples from an area measuring approximately 1 square meter, store them in clean and dry airtight containers, and then tag them. The area in specific is the asphalt pavement on the side of the road where it meets the curb. The tag should include the location and the color indicating the lockdown period. Three samples were collected per location for a total of 54 samples (n=54). To ensure safety and consistency, almost all the samples were collected on the same dates during low traffic evening time (around 9 pm). The first set of samples (n=18) was collected on the 30th of May 2020, which constitutes the full lockdown period. The second set (n=18) was collected on the 15th of June 2020, which constitutes the partial lockdown period. The last set of samples (n=18) was collected on the 16th of September 2020 during the re-opening period when all lockdown restrictions were lifted. The sample locations spanned most of the inhabited area of Kuwait from east to west. Most of the sample locations were on minor roads (15 out of 18), while half of the locations were near a city. The sample location coordinates, area names, and road descriptions are listed in *Table 3*. The sample locations can be found in *Figure 1*.

Table 3. *Sample locations and description*

Sample #	Coordinates	Area	Near a City	Road Description
1	29.3182835, 48.0023816	Surra	ü	Minor road, close to 4th ring road (Major)
2	29.3441940, 47.9762666	Abdullah Alsalim	ü	Major road (2nd ring road)
3	29.3094123, 48.0053927	Surra	ü	Minor road, close to 5th ring road and Damascus Road (Major)
4	29.3052637, 47.7140294	Saad Alabdullah		Minor Road, close to 6th ring road (Major)
5	29.3078196, 47.7287822	Saad Alabdullah		Minor Road, close to 6th ring road (Major)
6	29.3454189, 47.6906199	Alqasr		Minor Road
7	29.3103405, 48.0624159	Rumaithiya	ü	Minor Rod, Close to road 30 (Major)
8	29.2693021, 47.8651920	Sabah Alnaser		Major Road (6th ring road)
9	29.2823125, 47.9769801	Khaitan	ü	Minor road
10	29.3238342, 47.6729108	Alnaseem		Minor road
11	29.2945560, 48.0760723	Salwa	ü	Minor road
12	29.280685,47.984051	Khaitan	ü	Minor road, close to road 50 (major)
13	29.1989829, 48.1064393	Abu Fatira		Major road (30)
14	29.0893993, 48.0725737	Ahmadi		Minor road
15	29.2561619, 48.0692100	Sabah Alsalim		Minor road
16	29.340416, 47.655594	Waha		Minor road
17	29.3108782, 47.8761961	Granada	ü	Minor road, close to road 80 (major)
18	29.3422858, 47.9646007	Kaifan	ü	Minor road

Collection periods: 30/5/2020 at 9 pm (complete lockdown), 15/6/2020 at 9 pm (partial lockdown), and 16/9/2020 at 9 pm (re-opening)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

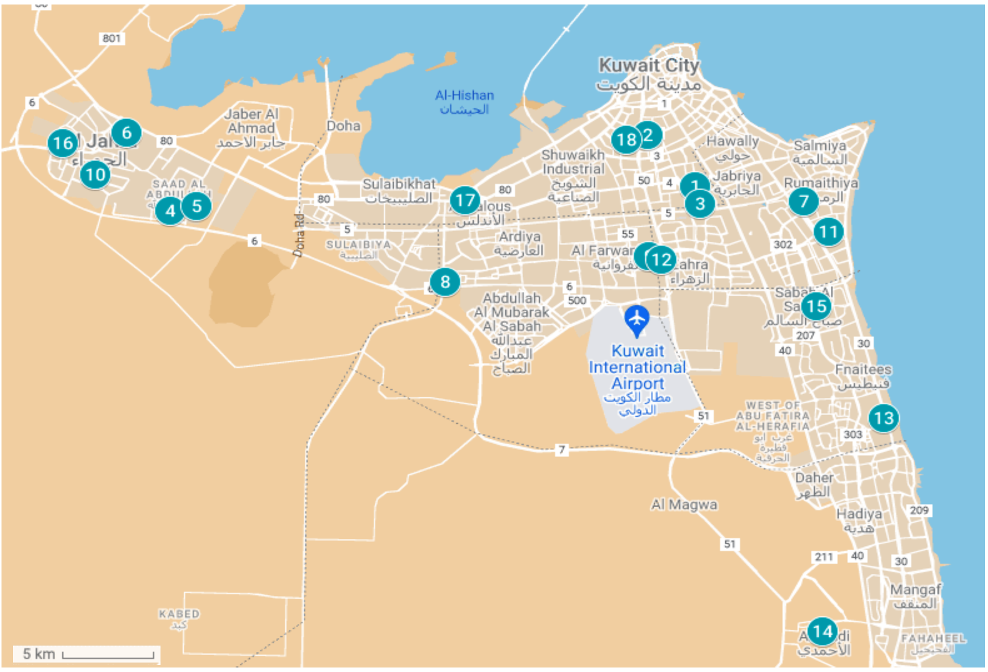

Figure 1. Sample locations map

Sample preparation and elemental composition analysis

Before chemical analysis, the collected samples (n=54, 18 locations x 3 periods) were sieved with a number 10 sieve (2 mm) for consistency purposes and aired out at room temperature. After sieving and drying, the samples were acid digested as a precursor for analysis by inductively coupled plasma atomic emission spectrometry (ICP-AES) as previously described by the EPA (Bettinelli et al., 2000) 3050B. In total, the tests were run on 156 samples as a triplicate of each sample was made for quality purposes. The atomic emission spectrometry usually provides data for many elements such as calcium and magnesium. However, the data of concern in this research are for the following heavy metals cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), vanadium (V), and zinc (Zn).

Statistical and environmental pollution analyses

A host of statistical tools and environmental pollution indices was employed to assess the role of lockdown on heavy metal concentrations. The statistical analysis included a correlation matrix of the heavy metals, identifying outliers, and descriptive statistics of the elemental concentrations. The environmental pollution indices were the enrichment factor (EF), geo-accumulation index (I_{geo}), the contamination factor (C_f^i), ecological risk potential (Er^i), and the risk index (RI).

The enrichment factor (EF) is one tool to assess the environmental health of a region and the degree of pollution. The enrichment factor is calculated by dividing the concentration of the collected sample after normalization by the concentration of the baseline value after normalization. The normalization role in the equation is critical as it tries to attribute the source concentrations to either natural or anthropogenic sources (Al-Awadhi and Al-Shuaibi, 2013). Aluminum, iron, and manganese can be used as normalizers as they are present in the soil's parent material or the earth's crust (Förstner

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

et al., 1993; Shafie et al., 2013; Abdullah et al., 2020). This research used manganese as the normalizer, showing the lowest variability and background concentration across the collected samples. It is also the element of choice for similar studies in the region (Al-Awadhi and Al-Shuaibi, 2013) and is associated with fine particulates, which is the type of sediments this research represents.

$$EF = \frac{\left(\frac{C_M}{C_x}\right)_{sample}}{\left(\frac{C_M}{C_x}\right)_{Background}} \quad \text{(Eq.1)}$$

where C_M is the concentration of the heavy metal (mg kg^{-1}) and C_x is the concentration of the normalizer (mg kg^{-1}). After calculating the enrichment factor values, the degree of contamination is assigned according to Sutherland 2000 categories, which are as follows: deficient to minimal enrichment (EF < 2), moderate enrichment ($2 \leq EF < 5$), significant enrichment ($5 \leq EF < 20$), very high enrichment ($20 \leq EF < 40$), and extremely high enrichment (EF > 40). The geo-accumulation index (I_{geo}) is one of the earliest environmental assessment indicators (Förstner et al., 1993). It classifies the samples in terms of sediment quality, and like the enrichment factor, it attempts to attribute the concentrations to natural or anthropogenic sources (Wang et al., 2020).

$$I_{geo} = Log_2\left(\frac{C_s}{1.5B_n}\right) \quad \text{(Eq.2)}$$

where Cs is the metal concentration in the collected sample, and Bn is the background concentration of the same metal. To reduce the natural lithologic variations the factor 1.5 is commonly used. According to Muller (1969) and Förstner et al. (1993), the sediments quality and classification are as follows: I-geo ≤ 0 (class 0) is practically unpolluted, 0 < I-geo < 1 (class 1) is unpolluted to moderately polluted, 1 < I-geo < 2 (class 2) is moderately polluted, 2 < I-geo < 3 (class 3) is moderately polluted to highly polluted, 3 < I-geo < 4 (class 4) is highly polluted, 4 < I-geo < 5 (class 5) is highly polluted to extremely polluted, I-geo ≥ 5 (class 6) is extremely polluted. The contamination factor (C_f^i), ecological risk potential (Er^i), and risk index (RI) are pollution analysis tools that are built on each other and can be integrated using the following general equation:

$$RI = \sum Tr^i \times C_f^i \quad \text{(Eq.3)}$$

where RI represents this risk index, Tr^i is the toxic-response factor for the heavy metal of concern, C_f^i is the contamination factor, and ($Tr^i \times C_f^i$) is the ecological risk potential (Er^i). The contamination factor is calculated by dividing the roadside sediment heavy metal concentration by the background concentration. To find the ecological risk potential values, the following toxic-response factors were used, 30, 5, 2, 5, 5, 5, 1 for cadmium, cobalt, chromium, copper, nickel, lead, and zinc respectively, according to Hakanson (1980) and Xu et al. (2008). According to Hakanson's categorization (1980), the ecological risk potential ranges from low ecological risk potential ($Er^i < 40$) to very high ecological risk potential ($Er^i \geq 320$), and the risk index (RI) ranges from low risk (RI < 150) to very high risk (RI ≥ 600).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

Commitment analysis during lockdown

The level of citizens' commitment to the national lockdown measures was attempted using google mobility data, and the official "curfew leave permissions" initiated by the public authority of civil information (PACI). PACI was requested the following data for curfew leave permissions: the total number of permissions during the partial and full-lockdown periods (including the collection dates), the level of commitment after obtaining the permissions, and the number of exceptions given to essential workers.

Results and Discussion

Elemental composition and descriptive statistics

The roadside deposited samples data from the ICP-AES analysis are shown in *Tables 4 and 5*. *Table 4* summarizes the elemental composition of the 162 tests (18 locations, three different collection periods, three subsamples per sample). Comparing the averages of the heavy metals for the three collection periods shows that the complete lockdown period had 5 of the lowest values (cadmium, copper, iron, lead, and vanadium) versus 2 for the partial lockdown (Manganese and Zinc) and 3 for the re-opening (cobalt, chromium, and nickel). Using the trimmed mean, which is a way to exclude extreme data points and describe the condition of the sediments more realistically, also shows that the full lockdown period had the lowest values overall (6 out 10 elements). The trimmed mean values also showed that most of the highest concentrations were during the re-opening period (Cu, Mn, Pb, V, and Zn). This is in line with the hypothesis of this paper, which predicted the environmental quality of the lockdown period to be better than the non-lockdown periods (partial and re-opening). This can be attributed mainly to the lockdown-associated governmental restrictions listed in *Table 2* and reduced vehicular traffic in specific. The rise of few concentrations during the full lockdown period (Co, Cr, and Ni) is not unexpected, as numerous factors influence the accumulation of heavy metals. For example, the governmental lockdown restrictions allowed for many exceptions, such as the activities and workers exempted from lockdown shown in *Table 2*. Another probable cause is the level of commitment to curfew leave permissions initiated by the public authority of civil information. Individuals are supposed to submit these requests online and get a QR code to show to the police if there is a police traffic stop.

Virtually all the minimum values were associated with the complete lockdown period (9 out of 10) and many maximum values. However, looking at the averages and trimmed means smoothing the data and confirming the relatively better sediment quality during the complete lockdown. The ranges of the heavy metals were highest during complete lockdown (8 out of 10) and lowest during re-opening (7 out of 10). The skew data show that concentrations are relatively symmetric overall apart from lead which was positively skewed across the three collection periods, and lead and copper to some extent. This indicates the presence of heavily polluted samples, thus influencing the respective means.

Correlation matrix

The correlation matrix based on the sample's elemental composition is shown in *Table 6*. Pearson's correlation coefficients indicate that all elements are positively correlated except for Cu-Cd, Cu-Cr, and Co-V, which had a very weak negative relationship of r=-0.15, r=-0.02, and r=-0.09, respectively.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

Table 4. *Descriptive statistics and elemental composition of the three collection periods (mg/kg)*

		Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Re-opening	Average	1.6	6.1	29.6	61.8	10647.1	159.7	71.7	14.9	20.3	65.6
	Trimmed Mean	1.5	5.9	28.5	31.4	10464.6	158.5	69.3	10.9	20.1	65.4
	Minimum	1.0	2.4	12.0	4.3	5580.9	58.9	19.7	2.0	5.3	6.7
	Maximum	2.7	13.0	64.6	605.7	18633.4	279.6	163.2	90.5	38.1	127.4
	Range	1.7	10.7	52.5	601.3	13052.5	220.7	143.5	88.5	32.8	120.8
	Skew	0.4	1.1	1.2	4.1	0.9	0.2	0.7	3.3	0.4	0.0
Partial Lockdown	Average	1.6	6.6	31.1	200.6	11124.1	156.1	80.7	21.5	18.2	59.1
	Trimmed Mean	1.6	6.5	30.5	30.9	10895.6	153.4	75.5	10.6	17.7	51.1
	Minimum	1.0	1.0	9.0	2.0	4203.0	58.7	9.2	1.7	6.0	3.0
	Maximum	3.0	14.0	63.1	3114.6	21702.2	296.3	235.4	215.1	37.6	244.1
	Range	2.0	13.1	54.1	3112.6	17499.2	237.6	226.3	213.4	31.6	241.1
	Skew	0.5	0.8	0.6	4.2	0.7	0.6	1.3	4.0	0.9	2.5
Complete lockdown	Average	1.6	7.0	33.3	24.9	10342.7	157.5	90.9	11.7	18.0	75.6
	Trimmed Mean	1.5	6.8	31.0	22.9	10155.3	155.4	86.6	9.7	17.5	50.2
	Minimum	1.0	1.0	5.3	1.3	2455.6	27.6	3.9	1.7	6.3	2.3
	Maximum	3.0	16.4	97.2	80.2	21227.9	321.0	246.6	54.0	38.8	554.9
	Range	2.0	15.4	91.8	78.8	18772.3	293.5	242.6	52.3	32.5	552.6
	Skew	0.7	0.8	1.7	1.5	0.5	0.4	0.9	2.7	1.1	3.9
	Background [18]	0.4	3.7	25.6	22.0	4162	121	25.6	4.6	19.2	18.4

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

Table 5. *Effects of restriction regimes on soil mineral levels (means in mg/kg)*

*Sample ID	Cd	Co	Cr	Co	Fe	Mn	Ni	Pb	V	Zn
Y1	1.34	4.35	20.74	11.04	7961	127.1	40.80	12.37	13.71	34.78
R1	1.67	3.67	20.36	9.34	8089	118.1	38.71	12.35	14.02	39.05
G1	2.02	5.73	37.42	55.63	12026	191.2	58.33	22.25	24.61	127.44
Y2	1.68	4.69	21.46	8.05	6931	112.6	57.66	9.05	12.40	23.47
R2	1.01	3.36	21.83	16.12	5706	92.4	38.29	10.41	10.41	26.87
G2	1.69	2.37	16.24	55.63	12026	191.2	32.14	2.03	20.30	13.20
Y3	2.01	4.68	23.76	23.42	9319	122.1	48.52	7.36	17.40	65.59
R3	2.01	6.02	25.09	25.43	9388	130.1	62.23	17.06	17.06	52.19
G3	2.01	7.37	34.51	47.91	12152	163.5	89.79	12.73	25.13	73.71
Y4	1.00	1.67	9.03	2.00	4203	79.6	10.70	3.68	11.04	3.01
R4	1.00	1.33	5.34	1.33	2456	42.4	6.68	1.67	6.34	9.33
G4	1.00	3.01	12.05	5.02	5581	58.9	19.74	3.68	13.38	7.03
Y5	1.34	4.69	27.95	9.39	9906	172.3	45.59	5.03	19.78	57.66
R5	2.01	6.03	33.83	56.27	13820	249.5	77.04	7.70	30.81	65.31
G5	2.01	4.35	26.41	8.02	10020	189.9	43.46	7.69	24.07	47.47
Y6	0.98	0.99	11.81	9.52	4960	58.7	9.10	5.58	10.50	54.47
R6	0.99	0.99	5.90	2.96	3789	27.6	3.94	2.32	16.07	2.33
G6	2.30	5.26	23.99	59.80	17503	144.2	42.71	4.62	15.44	66.70
Y7	2.02	7.39	34.95	99.81	14655	226.2	55.11	215.08	37.64	91.07
R7	1.97	5.26	36.16	24.33	14371	222.9	53.59	9.21	38.79	74.30
G7	2.01	4.35	32.49	25.12	11795	198.3	48.56	7.03	36.84	98.46
Y8	2.02	7.06	34.62	23.87	10535	176.5	80.68	14.12	18.15	67.23
R8	2.02	12.11	97.19	22.87	12507	172.5	199.09	16.48	14.46	67.59
G8	0.98	5.91	27.24	30.20	8453	134.6	81.40	17.72	12.80	63.67
Y9	3.00	5.33	25.34	18.67	21702	157.0	51.34	5.33	14.33	21.00
R9	1.00	5.01	32.06	9.35	9173	187.7	57.11	3.34	9.69	32.73
G9	1.00	2.67	12.02	4.36	6949	90.2	20.71	4.01	9.02	6.68

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

*Sample ID	Cd	Co	Cr	Co	Fe	Mn	Ni	Pb	V	Zn
Y10	2.01	14.05	50.84	28.10	17911	296.3	201.35	9.37	26.76	72.58
R10	2.02	14.78	41.21	18.48	14539	224.4	246.57	6.38	16.12	50.05
G10	1.33	6.00	27.67	25.34	10899	207.0	60.01	9.67	19.00	113.02
Y11	1.96	13.10	35.04	30.78	12414	165.7	235.44	3.93	13.10	25.21
R11	1.00	8.01	28.04	14.69	9312	116.9	129.54	8.01	11.69	19.03
G11	1.31	7.20	32.09	22.27	9236	133.3	112.32	8.51	14.08	27.51
Y12	1.00	7.01	24.38	11.02	8043	83.5	113.54	1.67	6.01	8.35
R12	1.00	4.01	22.71	24.37	7452	108.5	49.75	4.67	10.02	554.94
G12	1.00	6.01	13.68	14.35	5742	67.4	98.43	8.01	5.34	10.34
Y13	2.01	7.38	42.26	103.30	12959	175.1	84.52	13.42	16.43	79.48
R13	1.31	12.12	35.37	20.63	10863	139.5	183.39	6.55	10.48	37.99
G13	1.64	8.85	26.23	28.52	10225	141.9	132.11	4.26	9.83	43.93
Y14	0.98	3.94	43.33	26.59	8707	117.9	31.84	5.91	19.70	30.86
R14	1.97	5.92	25.65	26.96	10673	167.4	52.28	5.92	20.39	64.12
G14	1.31	4.92	22.95	32.79	9280	131.8	39.02	7.54	18.36	45.25
Y15	0.98	3.93	21.95	12.78	7501	135.3	35.71	5.90	21.95	25.88
R15	0.98	3.93	21.27	11.45	8224	128.6	31.08	53.99	18.98	28.14
G15	0.99	5.59	33.20	36.16	9959	181.8	45.69	9.91	38.13	92.04
Y16	1.97	13.14	63.09	42.39	17013	252.7	161.99	40.41	28.59	67.36
R16	3.01	16.39	71.23	45.81	21228	321.0	206.33	33.11	35.78	76.58
G16	2.68	13.04	64.55	64.22	18633	279.6	163.22	37.80	30.77	127.10
Y17	2.01	9.04	43.53	36.16	14191	231.0	100.12	9.04	27.79	92.08
R17	1.97	9.20	46.66	37.13	15679	259.2	99.89	12.16	31.54	104.16
G17	1.97	10.20	59.20	38.81	15560	252.3	126.30	9.54	29.93	103.93
Y18	1.00	6.34	26.71	3114.63	11323	119.5	88.15	19.03	11.69	244.08
R18	1.00	7.32	29.06	80.16	8902	126.3	101.20	8.35	12.02	55.78
G18	0.98	6.56	30.50	605.65	10042	153.8	77.06	90.50	18.04	112.47

*Y – Samples obtained during partial lockdown; R – Samples obtained during complete lockdown; G – samples obtained during reopening

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

Table 6. *correlation matrix based on sample's elemental composition*

	Cadmium	Cobalt	Chromium	Copper	Iron	Manganese	Nickel	Lead	Vanadium	Zinc
Cadmium	1									
Cobalt	0.541	1								
Chromium	0.561	0.797	1							
Copper	-0.147	0.013	-0.016	1						
Iron	0.831	0.722	0.705	0.045	1					
Manganese	0.700	0.713	0.748	-0.056	0.846	1				
Nickel	0.414	0.958	0.706	0.028	0.570	0.552	1			
Lead	0.124	0.147	0.171	0.099	0.224	0.254	0.024	1		
Vanadium	0.534	0.311	0.491	-0.088	0.596	0.770	0.116	0.362	1	
Zinc	0.026	0.084	0.165	0.331	0.159	0.180	0.042	0.101	0.129	1

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

Strong positive correlations were between the following pairs Cd-Fe, Cd-Mn, Co-Cr, Co-Fe, Co-Mn, Co-Ni, Cr-Fe, Cr-Mn, Cr-Ni, Fe-Mn, and Mn-V, and their r values were 0.83, 0.70, 0.80, 0.72, 0.71, 0.96, 0.71, 0.75, 0.71, 0.85, and 0.77, respectively. The abovementioned pairs also showed statistical significance ($p<0.001$). Most of these pairs had cobalt, iron, and manganese. Iron and manganese are usually of geochemical origin, indicating that the heavy metals paired with them (Cd, Co, Cr, and V) could be of geochemical origin. These positive correlations suggest that the roadside sediments share a common source (Zhang and Hao, 2009). Lead, zinc, and copper had weak correlations with other elements.

Contamination factors, ecological risk potential, risk index, and enrichment factors

The contamination factor analysis shows that fifty percent of the heavy metals had their lowest values during the complete lockdown period. The full lockdown period had lower overall categories, followed by re-opening and partial lockdown periods. The complete lockdown contamination factor categories were as follows: Pb and V were in the first category or low contamination ($C_f^i < 1$), Co, Cr, Cu, Fe, and Mn were in the second category or moderate contamination ($1 \leq C_f^i < 3$), the rest of the metals (Cd, Ni, and Zn) were in the lower range of the third category or considerable contamination ($3 \leq C_f^i < 6$). The highest contamination factor and category was for copper during the partial lockdown period ($C_f^i = 9.1$). The contamination factor was relatively high and uniform for Cd and Zn across the three periods while relatively low and uniformed for Co, Cr, Mn, and V across the three periods.

Almost all sediments showed low ecological risk potential ($Er^i < 40$) according to Hakanson's terminology (Haris and Aris, 2013), except for cadmium (all three periods) and copper (partial lockdown). Cadmium values ranged from 116 (full lockdown) to 122 (partial lockdown) which is classified as category 3 ($80 \leq Er^i < 160$) or considerable ecological risk potential. Cadmium risk potential values are due to its high toxicity and correspond to Hakanson's toxic response factor, which is 30 compared to other metals 1~5. Apart from Cd, Cu, and Pb, all heavy metals showed relatively low ecological risk potential ($Er^i < 20$) across the three collection periods. The risk index (RI), which combines the ecological risk potential data into a single indicator (except for manganese following recommendations by Hakanson (1980), showed that during the complete lockdown, it was the lowest (RI = 162.2). However, all three-study periods were in the same category ($150 \leq RI < 300$) or moderate ecological risk. As for the enrichment factor (EF), virtually all sediments showed minimal to moderate enrichment across the three collection periods (EF = 0.7-3.6); the exception was Cu during the partial lockdown, which had significant enrichment (EF=7.1), which is in the lower range of the third category ($5 \leq EF < 20$). All contamination factors, ecological risk potential, risk index, and enrichment factors are shown in *Table 7*.

The above host of environmental pollution indices showed that the role of lockdown on heavy metal concentrations is minimal or moderate at best when the reference is the re-opening period. However, changing the reference to pre-pandemic, the pollution indices show significant improvements. For example, comparing enrichment factors to pre-pandemic levels, which Al-Awadhi and Al-Shuaibi (2013) computed, show that most heavy metals are well below the pre-pandemic levels (*Figure 2*), including the re-opening period when somewhat all lockdown measures are lifted (note: point A represents the Cu's actual mean where the bar represents the trimmed mean as it was highly influenced by the maximum value which might be an outlier). The ecological risk index (RI) was

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

also below the level reported by Alsanad and Alolayan (2020) for residential areas (pre-pandemic = 254.8, full lockdown = 162.2, partial lockdown = 226.0, and re-opening = 180.6). This improvement in environmental quality is expected as lockdown measures such as limited commercial activities and reduced workplace capacity up to 30% (*Table 2*) reduced people and vehicular mobility, which reduced vehicle-related and road-related deposited sediments such as sediments exhaust emissions and asphalt wear (*Table 1*). On the contrary, the lack of significant improvement in environmental quality across the study's three collection periods is complicated. For the case of cadmium, the disparity of the observed levels when compared to pre-pandemic levels cannot be assigned to a specific factor with absolute certainty. The factors influencing the accumulation of heavy metals and cadmium specifically are not limited to transportation and commercial activities which were heavily reduced during the pandemic. One would assume that some Cd-producing sources emerged after the pre-pandemic study which was conducted in 2013 resulted in the observed increases in cadmium (*Table 8*). However, no known anthropogenic sources were added, and we believe this is attributed to the increase in waste incineration or cement manufacturing (Pollution Prevention and Abatement Handbook, 1998).

Table 7. *Contamination factors, ecological risk potential, risk index, and enrichment factors*

		Re-opening	Partial	Full			Re-opening	Partial	Full
Cd	Cfi	3.9	4.1	3.9	Mn	Cfi	1.3	1.3	1.3
	Er	117.7	122.2	116.4		Er	1.3	1.3	1.3
	EF	3.0	3.2	3.0		**EF**	1.0	1.0	1.0
Co	Cfi	1.6	1.8	1.9	Ni	Cfi	2.8	3.2	3.6
	Er	8.2	8.9	9.4		Er	14.0	15.8	17.8
	EF	1.2	1.4	1.4		**EF**	2.1	2.4	2.7
Cr	Cfi	1.2	1.2	1.3	Pb	Cfi	3.2	4.7	0.4
	Er	2.3	2.4	2.6		Er	16.2	23.3	1.8
	EF	0.9	0.9	1.0		**EF**	2.4	3.6	2.0
Cu	Cfi	2.8	9.1	1.1	V	Cfi	1.1	0.9	0.9
	Er	14.0	45.6	5.7		Er	2.1	1.9	1.9
	EF	2.1	7.1	0.9		**EF**	0.8	0.7	0.7
Fe	Cfi	2.6	2.7	2.5	Zn	Cfi	3.6	3.2	4.1
	Er	2.6	2.7	2.5		Er	3.6	3.2	4.1
	EF	1.9	2.1	1.9		**EF**	2.7	2.5	3.2
RI (Cd, Co, Cr, Cu, Fe, Ni, Pb, V, and Zn)							180.6	226.0	162.2

The hypothesis that full lockdown sediment quality should be better than partial lockdown and partial lockdown better than the re-opening period assumes that people and businesses abide by lockdown measures initiated by the government, especially in phases 1 and 2 (*Table 2*). Even though the complete lockdown period had relatively better sediment quality, the sequence (complete lockdown < partial lockdown < re-opening) was not as expected due to several contributing factors. First, as mentioned above, the level of commitment in the official curfew leave permissions initiated by the public authority of civil information (PACI) was not up to par as we believe it was abused and sometimes is not requested to begin with. According to PACI, the total number of permissions given

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

during 2020 was 1,746,228, while in 2021, it was 1,182,892. The collection days in specific had the following curfew leave permissions 27,101 on 30/5/20 (complete lockdown) and 7,242 on 15/6/20 (partial lockdown) (PACI, 2021).

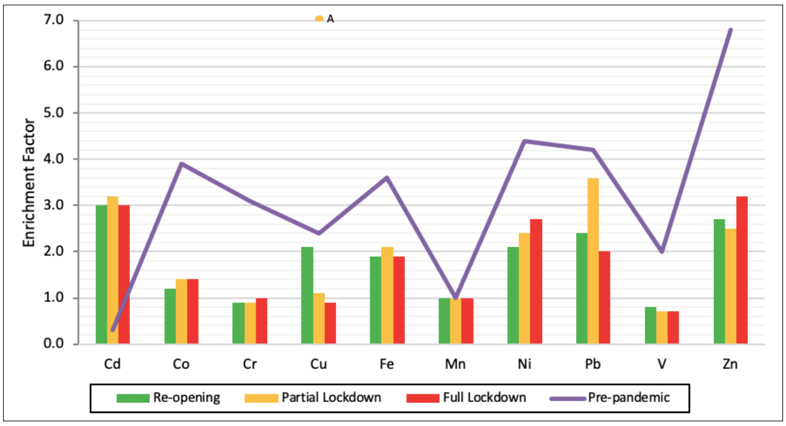

Figure 2. *Enrichment factors (from table 8) across study periods*

Covid-19 community mobility data shown in *Figure 3* might be a better indicator of the commitment levels of the public. This data is derived from those who opted-in Google's location history. During the five-week study, the obtained median value was designated as the baseline for the corresponding day of the week (CMR, 2022). The data shows that mobility was limited in most venues, including retail shops, transit stations, and workplaces while increasing in residential places. For example, there was a 72% decline in mobility during the complete lockdown in workplaces while a 36% increase in residential places. The trend is clear, as the most decline was observed in complete lockdown and then partial lockdown re-opening, and all were lower than pre-pandemic values.

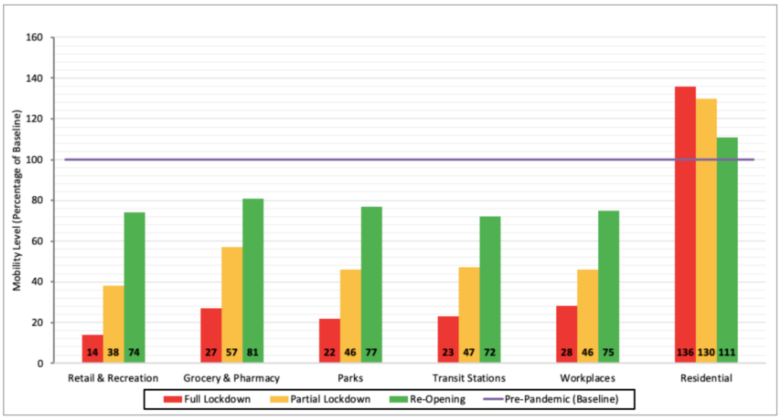

Figure 3. *Covid-19 Community Mobility data based on community mobility reports (CMR, 2022)*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

Table 8. *Geo-accumulation indices and classes*

		Cd		Co		Cr		Cu		Fe		Mn		Ni		Pb		V		Zn	
		I-geo	Class	I-geo	Class	I-geo	Class	I-geo	Class	I-geo	Class	I-geo	Class	I-geo	Class	I-geo	Class	I-geo	Class	I-geo	Class
Re-opening	Avg	1.4	2.0	3.3	4.0	5.6	6.0	6.7	6.0	14.1	6.0	8.1	6.0	6.9	6.0	4.6	5.0	5.1	6.0	6.8	6.0
	Min	0.7	1.0	2.0	2.0	4.3	5.0	2.9	3.0	13.2	6.0	6.6	6.0	5.0	6.0	1.8	2.0	3.2	4.0	3.5	4.0
	Max	2.2	3.0	4.4	5.0	6.7	6.0	10.0	6.0	14.9	6.0	8.9	6.0	8.1	6.0	7.2	6.0	6.0	6.0	7.7	6.0
Partial Lockdown	Avg	1.4	2.0	3.5	4.0	5.7	6.0	8.4	6.0	14.2	6.0	8.0	6.0	7.1	6.0	5.2	6.0	4.9	5.0	6.6	6.0
	Min	0.7	1.0	0.7	1.0	3.9	4.0	1.7	2.0	12.8	6.0	6.6	6.0	3.9	4.0	1.5	2.0	3.3	4.0	2.3	3.0
	Max	2.3	3.0	4.5	5.0	6.7	6.0	12.3	6.0	15.1	6.0	8.9	6.0	8.6	6.0	8.5	6.0	6.0	6.0	8.7	6.0
Complete Lockdown	Avg	1.4	2.0	3.5	4.0	5.8	6.0	5.4	6.0	14.1	6.0	8.0	6.0	7.2	6.0	4.3	5.0	4.9	5.0	7.0	6.0
	Min	0.7	1.0	0.7	1.0	3.2	4.0	1.2	2.0	12.0	6.0	5.5	6.0	2.7	3.0	1.5	2.0	3.4	4.0	2.0	2.0
	Max	2.3	3.0	4.8	5.0	7.3	6.0	7.1	6.0	15.1	6.0	9.1	6.0	8.7	6.0	6.5	6.0	6.0	6.0	9.9	6.0

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

The level of commitment can be estimated as well using the official ministry of commerce and industry (MOCI) monthly supermarkets reservations reports, which showed that on May 17, 2020, the reservations showed up ratio was 56%, and on June 7, 2022, the ratio was 44% (KMOCI, 2022). Second, according to Kuwait Municipality officials (Al-Awadhi and AlShuaibi, 2013; Khattab, 2020), the garbage collectors, waste compactors, and road sweeping (manual and mechanical) did not stop during partial and complete lockdowns. The workers were considered essential workers and were allowed to continue working daily from 4 am to 8 am. This action reduces the variation in the concentrations of heavy metals from period to period and explains the relatively comparable values found in *Table 7*. The continued municipality actions somehow reset the sediment quality every morning. Third, due to lockdown and limited outdoor activities, most people stayed indoors longer, and in a hot May climate like Kuwait's, the energy consumption, especially by air conditioning, is high. As Kuwait's energy demands are nearly entirely met by oil products and natural gas, the sediments might be slightly elevated during the lockdown (Kuwait Energy Outlook, 2019). All contamination factors, ecological risk potential, risk index, and enrichment factors are shown in *Table 7*. *Figure 4* scales ecological risk values for all studied elements across the collection periods. The midlines represent the average values, with the red bar's midline being the basline (average value of complete lockdown). All other lines such as maximums and minimums are relative to baseline. It can be seen that the re-opening period bars are mostly engulfing other bars meaning that ecological risk is greater during re-opening with very few exeptions. Our findings that lowest risk indicator was recorded during the complete lockdown phase agrees with recent reports (Singh et al., 2022; Chowdhuri, 2022; Rabin, 2022), and deposition increased with the easing of restrictions. While this is obvious, it is important that government at various levels in Kuwait consider regulating the use of fossil fuel vehicles to lower deposition levels and improve environmental quality. Policies in this regard may be useful in enhancing health and wellbeing. The pandemic may have presented numerous negative effects globally but this study presents some positive perspectives which creates opportunities for the Kuwaiti government and its stakeholders on how effective regulations at various levels can be reviewed to improve life, living and the environment without compromising quality. The clamour for renewable energy sources, vehicles and facilities can be an ambitious but cost-effective strategy in the long-term (Eckhouse, 2022; Kumar, 2022; Newell et al., 2022). It is anticipated that further studies assessing the feasibility of these initiatives be conducted to provide robust data dor government and policymakers in Kuwait. This would set the pace for other developing countries in the region as well.

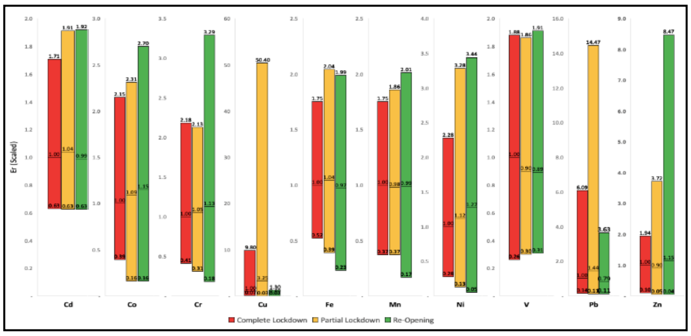

Figure 4. *Ecological risk (Er) values across the collections periods relative to baseline (complete lockdown)*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

Conclusion

This research tried to capitalize on probably one in life event. Using the available information, this research data suggests that the partial lockdown and full lockdown measures showed minor improvements in environmental quality as the roadside sediments from the lockdown periods had lower heavy metals concentrations. Specifically, the complete lockdown-associated governmental restrictions such as reduced human and vehicular mobility were slightly more effective in lowering heavy metal concentrations. Most of the highest concentrations were during the re-opening period (Cu, Mn, Pb, V, and Zn), while the full lockdown period had the lowest values overall (6 out 10 elements). This is in line with the hypothesis of this paper, which predicted the environmental quality of the lockdown period to be better than the non-lockdown periods (partial and re-opening). However, we believe the improvement in sediment quality between the different periods was minimal due to factors such as low levels of commitment in the governmental curfew leave permissions, the continuity of manual and mechanical road cleanup processes by Kuwait municipality during lockdowns, and the energy consumption associated emissions resulting from extended indoor stay. The following is recommended for future research on this topic, more than one sample per period per location might be needed for the data to be more representative, official detailed lockdown leave data from the governmental organizations should be available to researchers, and finally, comparing the roadside sediments with ambient air pollution data to exclude external environmental factors.

Acknowledgments. This research project (SRUL01/13) would not be possible without the support of the National Unit of Environmental Research and Services (NUERS) at Kuwait University, Alberto Orayan, Melba Kishor, and Alia Awan for their help in running and coordinating the required laboratory tests, V. R. for providing mobility data and Smith proofreading the manuscript, and the public authority of civil information (PACI) for providing the lockdown leave requests data.

REFERENCES

[1] Abdullah, M., Sah, A., Haris, H. (2020): Geoaccumulation Index and Enrichment Factor of Arsenic in Surface Sediment of Bukit Merah Reservoir, Malaysia. – Tropical Life Sciences Research 31(3): 109-125.

[2] Al-Awadhi, J. M., Al-Shuaibi, A. A. (2013): Dust fallout in Kuvait city: Deposition and characterization. – Science of the Total Environment 461-462: 139-148.

[3] Alsanad, A., Alolayan, M. (2020): Heavy metals in road-deposited sediments and pollution indices for different land activities. – Environmental Nanotechnology, Monitoring & Management 14: 100374.

[4] Alves, C. A., Vicente, A. M. P., Calvo, A. I., Baumgardner, D., Amato, F., Querol, X., Gustafsson, M. (2020): Physical and chemical properties of non-exhaust particles generated from wear between pavements and tyres. – Atmospheric Environment 224: 117252.

[5] Bettinelli, M., Beone, G. M., Spezia, S., Baffi, C. (2000): Determination of heavy metals in soils and sediments by microwave-assisted digestion and inductively coupled plasma optical emission spectrometry analysis. – Analytica Chimica Acta 424(2): 289-296.

[6] Charlesworth, S., Everett, M., McCarthy, R., Ordonez, A., De Miguel, E. (2003): A comparative study of heavy metal concentration and distribution in deposited street dusts in a large and a small urban area: Birmingham and Coventry, West Midlands, UK. – Environment International 29(5): 563-573.

[7] Chowdhuri, I., Pal, S. C., Arabameri, A., Ngo, P. T. T., Roy, P., Saha, A., Chakrabortty, R. (2022): Have any effect of COVID-19 lockdown on environmental sustainability? A study from most polluted metropolitan area of India. – Stochastic Environmental Research and Risk Assessment 36(1): 283-295.
[8] Community Mobility Reports (CMR) (2022): Available at: https://support.google.com/covid19-mobility/answer/9824897?hl=en. Accessed on 10/03/2022).
[9] Duzgoren-Aydin, N. S., Wong, C. S. C., Song, Z. G., Aydin, A., Li, X. D., You, M. (2006): Fate of heavy metal contaminants in road dusts and gully sediments in Guangzhou, SE China: A chemical and mineralogical assessment. – Human and Ecological Risk Assessment: An International Journal 12(2): 374-389.
[10] Eckhouse, J. G. (2022): Carbon Purgatory: The Dysfunctional Political Economy of Oil During the Renewable Energy Transition. – Doctoral dissertation, UC Berkeley.
[11] Förstner, U., Ahlf, W., Calmano, W. (1993): Sediment quality objectives and criteria development in Germany. – Water Science and Technology 28(8-9): 307-316.
[12] Hakanson, L. (1980): An ecological risk index for aquatic pollution control: A sedimentological approach. – Water Research 14(8): 975-1001.
[13] Haleem, A., Javaid, M., Vaishya, R. (2020): Effects of COVID-19 pandemic in daily life. – Current Medicine Research and Practice 10(2): 78.
[14] Hanfi, M. Y., Mostafa, M. Y., Zhukovsky, M. V. (2020): Heavy metal contamination in urban surface sediments: sources, distribution, contamination control, and remediation. – Environmental Monitoring and Assessment 192(1): 1-21.
[15] Haris, H., Aris, A. Z. (2013): The geoaccumulation index and enrichment factor of mercury in mangrove sediment of Port Klang, Selangor, Malaysia. – Arabian Journal of Geosciences 6(11): 4119-4128.
[16] Hoertel, N., Blachier, M., Blanco, C., Olfson, M., Massetti, M., Rico, M. S., Leleu, H. (2020): A stochastic agent-based model of the SARS-CoV-2 epidemic in France. – Nature Medicine 26(9): 1417-1421.
[17] Hong, N., Guan, Y., Yang, B., Zhong, J., Zhu, P., Ok, Y. S., Liu, A. (2020): Quantitative source tracking of heavy metals contained in urban road deposited sediments. – Journal of Hazardous Materials 393: 122362.
[18] Jeong, H., Choi, J. Y., Ra, K. (2021): Potentially toxic elements pollution in road deposited sediments around the active smelting industry of Korea. – Scientific Reports 11(1): 1-12.
[19] Khattab, D. (2020): Alanba accompanied the municipality's teams during a cleaning tour in the corridors of Al-Mubarakiya. – Available at: https://www.alanba.com.kw/ar/exclusive-reports/972864/07-06-2020-%D8%A8%D8%A7%D9%84%D9%81%D9%8A%D8%AF%D9%8A%D9%88-%D8%A7%D9%84%D8%A3%D9%86%D8%A8%D8%A7%D8%A1-%D8%B1%D8%A7%D9%81%D9%82%D8%AA-%D9%81%D8%B1%D9%82-%D8%A7%D9%84%D8%A8%D9%84%D8%AF%D9%8A%D8%A9-%D8%AE%D9%84%D8%A7%D9%84-%D8%AC%D9%88%D9%84%D8%A9-%D9%86%D8%B8%D8%A7%D9%81%D8%A9-%D8%A3%D8%B1%D9%88%D9%82%D8%A9-%D8%A7%D9%84%D9%85%D8%A8%D8%A7%D8%B1%D9%83%D9%8A%D8%A9/. Accessed on June 7, 2020.
[20] Kim, D. G., Kim, H. S., Kang, H. M., Ko, S. O. (2016): Pollutant characteristics of road deposited sediments collected by road sweeping. – Water Science and Technology 74(1): 194-202.
[21] Kim, D. G., Kang, H. M., Ko, S. O. (2019): Reduction of non-point source contaminants associated with road-deposited sediments by sweeping. – Environmental Science and Pollution Research 26(2): 1192-1207.
[22] Kumar, S. (2022): Status of Sustainable Procurement Implementation. – In: Understanding Sustainable Public Procurement, Springer, Cham., pp. 87-151.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094

[23] Kuwait Energy Outlook (2019): Sustaining prosperity through strategic energy management. – Available at: https://www.undp.org/content/dam/rbas/doc/Energy%20and%20Environment/KEO_report_English.pdf.
[24] Kuwaiti Ministry of Commerce and Industry (KMOCI) (2022): Available at https://www.moci.gov.kw/ar/media/news/. Accessed on 20/03/2022.
[25] Lanzerstorfer, C. (2018): Heavy metals in the finest size fractions of road-deposited sediments. – Environmental Pollution 239: 522-531.
[26] Loganathan, P., Vigneswaran, S., Kandasamy, J. (2013): Road-deposited sediment pollutants: a critical review of their characteristics, source apportionment, and management. – Critical Reviews in Environmental Science and Technology 43(13): 1315-1348.
[27] Men, C., Liu, R., Wang, Q., Guo, L., Shen, Z. (2018): The impact of seasonal varied human activity on characteristics and sources of heavy metals in metropolitan road dusts. – Science of the Total Environment 637: 844-854.
[28] Moser, C., Yared, P. (2021): Pandemic lockdown: The role of government commitment. – Review of Economic Dynamics 46: 27-50.
[29] Muller, G. M. (1969): Index of geoaccumulation in sediments of the Rhine River. – Geojournal 2: 108-118.
[30] Newell, P., Daley, F., Twena, M. (2022): Changing Our Ways? Behaviour Change and the Climate Crisis. – Elements in Earth System Governance.
[31] Niyogi, A., Pati, J. K., Patel, S. C., Panda, D., Patil, S. K. (2011): Anthropogenic and impact spherules: Morphological similarity and chemical distinction–A case study from India and its implications. – Journal of Earth System Science 120(6): 1043-1054.
[32] Pollution Prevention and Abatement Handbook (1998): Cadmium. – Available at: https://www.ifc.org/wps/wcm/connect/79dacedf-d718-4083-b469-e02888d2b18b/HandbookCadmium.pdf?MOD=AJPERES&CVID=jqewtkB. Accessed on May 14, 2022.
[33] Public Authority for Civil Information PACI (2021): Leave Permission Request During Curfew. – Available at: https://curfew.paci.gov.kw/request/create. Accessed on January 10, 2022.
[34] Quiñonez-Plaza, A., Wakida, F. T., Temores-Peña, J., Rodriguez-Mendivil, D. D., Garcia-Flores, E., Pastrana-Corral, M. A., Melendez-Lopez, S. G. (2017): Total petroleum hydrocarbons and heavy metals in road-deposited sediments in Tijuana, Mexico. – Journal of Soils and Sediments 17(12): 2873-2886.
[35] Rabin, M. H., Wang, Q., Kabir, M. H., Wang, W. (2022): Pollution characteristics and risk assessment of potentially toxic elements of fine street dust during COVID-19 lockdown in Bangladesh. – Environmental Science and Pollution Research.
[36] Ren, X. (2020): Pandemic and lockdown: a territorial approach to COVID-19 in China, Italy and the United States. – Eurasian Geography and Economics 61(4-5): 423-434.
[37] Shafie, N. A., Aris, A. Z., Zakaria, M. P., Haris, H., Lim, W. Y., Isa, N. M. (2013): Application of geoaccumulation index and enrichment factors on the assessment of heavy metal pollution in the sediments. – Journal of Environmental Science and Health, Part A 48(2): 182-190.
[38] Singh, M., Pandey, U., Pandey, J. (2022): Effects of COVID-19 lockdown on water quality, microbial extracellular enzyme activity, and sediment-P release in the Ganga River, India. – Environmental Science and Pollution Research 29(40): 60968-60986.
[39] State of Kuwait (2022): Live Covid-19 updates and lockdown phase plans. – Available online at: https://corona.e.gov.kw/En/. Accessed on January 14, 2022.
[40] Tirachini, A., Cats, O. (2020): COVID-19 and public transportation: Current assessment, prospects, and research needs. – Journal of Public Transportation 22(1): 1.

[41] Wang, Q., Zhang, Q., Wang, X. C., Ge, Y. (2020): Size distributions and heavy metal pollution of urban road-deposited sediments (RDS) related to traffic types. – Environmental Science and Pollution Research 27(27): 34199-34210.
[42] Wang, Q., Zhang, Q., Wang, X. C., Huang, J., Ge, Y. (2020): Impacts of key factors on heavy metal accumulation in urban road-deposited sediments (RDS): Implications for RDS management. – Chemosphere 261: 127786.
[43] Wei, X., Gao, B., Wang, P., Zhou, H., Lu, J. (2015): Pollution characteristics and health risk assessment of heavy metals in street dusts from different functional areas in Beijing, China. – Ecotoxicology and Environmental Safety 112: 186-192.
[44] Xu, Z. Q., Ni, S. J., Tuo, X. G., Zhang, C. J. (2008): Calculation of heavy metals' toxicity coefficient in the evaluation of potential ecological risk index. – Environmental Science and Technology 31(2): 112-5.
[45] Yuen, J. Q., Olin, P. H., Lim, H. S., Benner, S. G., Sutherland, R. A., Ziegler, A. D. (2012): Accumulation of potentially toxic elements in road deposited sediments in residential and light industrial neighborhoods of Singapore. – Journal of Environmental Management 101: 151-163.
[46] Zhang, M., Hao, W. (2009): Concentrations and chemical forms of potentially toxic metals in road-deposited sediments from different zones of Hangzhou, China. – Journal of Environmental Sciences 21(5): 625-631.
[47] Zhao, H., Li, X., Wang, X. (2011): Heavy metal contents of road-deposited sediment along the urban–rural gradient around Beijing and its potential contribution to runoff pollution. – Environmental Science & Technology 45(17): 7120-7127.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2102_10751094