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STUDY ON PHYSICOCHEMICAL AND LEVELS OF SELECTED METALS IN THE SOILS OF ABUJA METROPOLIS, NIGERIA

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ABSTRACT

A study of Abuja soils was carried out to determine physicochemical parameters and levels of selected metals. Flame atomic absorption spectrometer was used to determine total metal concentration. Aqua-regia (HCl-HNO_3-H_2O in the ratio 1:1:1) for the determination of the concentrations of Zn, Mn, Cu and As in the soils was employed also. Range of urban soil parameters were: electrical conductivity(16.20±0.20-374±0.50), pH(6.30±0.30-7.20±0.20), SO_4(7.40±0.40-127.35±0.07)and Cl (25.02±0.02-65.05±0.01). Range of parameters in sub urban soil samples were: EC(12.10±0.10–269.05±0.05), pH(2.20±0.20-7.20±0.20),SO_4(11.25±0.0766.35±0.07)and Cl(40.02±0.02–60.02±0.03).Sequence of metals concentrations in urban soils is as follows: Zn>Cu>Mn>As, sub urban soil samples had :Zn>Cu>Mn>As. Excess SO_4 in Abuja soils can devastate the environment with acid rain. Excess Cl in Asokoro Forest portends danger to the environment as it destroys plants and aquatic habitat. Excess Zn in the soils inhibits photosynthesis in plants, thereby increasing the amount of CO_2 in the atmosphere, causing global warming and also excess Cu in Abuja soils can interfere in the decomposition and other microbial activities in the soils, thereby affecting soil balance. An effective measure such as environmental risk assessment should be conducted periodically by relevant authorities towards controlling Zn contents in Abuja soils in order to reduce global warming.

Keywords: Urban soil, Sub urban soil, Physicochemical Parameters, Global warming and Metals

INTRODUCTION

An urban area is an environment in which anthropological activities are in high prevalence, population growth is high and not distributed equally with large consumption of resources and with resultant high output of polluted materials (Salvati, 2019). It is also defined as a region surrounding a city and most inhabitants have non-agricultural jobs (Orgiazzi *et al*., 2016). Urban areas are strongly characterized by a large percentage of impervious area, in a general process that has been termed surface sealing (Charzynski *et al*., 2018). According to United Nations Department of Economics and Social Affairs (UN DESA), cities are important driving forces in environmental trends as a consequence of the increase in the share of the global population that resides in urban areas and the large intensity of activities of urban dwellers (UN DESA, 2018).
Overcrowded urban areas are exposed to heavy loads of toxic metals and polyaromatic hydrocarbons (Galmez *et al*, 2019). According to United Nations Population Fund (UNFP), by 2050 the global urban population will increase by 2.5 billion and the population of global urban population will reach 66% nearly 90% of which is concentrated in Asia and Africa and countries with the largest increase in urban population will be India, China and Nigeria (Li, 2017). Urban soils are distinguishable within urban environments, as physical, chemical and biological properties are modified by a significant site disturbance for urban infrastructure (Recanatesi *et al*., 2016). Air pollution, topsoil contamination, surface and ground water contaminations are all made inevitable by urban development (Sasakova *et al*., 2018). Climate change and landscape transformation have led to rapid expansion of sub-urban areas globally (Samaneh *et al*., 2022). Sub urban areas are defined as the areas of transition or interaction zone, where urban and rural activities are combined and landscape features are subject to rapid modification induced by human activities (Douglas, 2015). Sub-urban lands are routinely used worldwide for intensive farming activities especially vegetable farming; many farmers normally apply fertilizers and pesticides to help improve crop yield and quality (Konwaruk *et al*, 2021). Thus, the sub-urban area generally contains residential land, industrial and other land use types, the area provides essential ecosystem service for urban and rural residents (Li *et al*, 2019). The phenomenon of urbanisation affecting this era has seen the shift of the city from compact and well-defined structures to agglomerations with a seamless expansion which makes peri urban areas the main urban design and planning challenge of the 21st century (Vindigni *et al*.,2021). Metals could also cause phytotoxicity in plants. Zn phytotoxicity for instance, includes the disruption of photosynthesis in plants which could increase the amount of CO_2 in the atmosphere. This study intends to emphasize on this issue in order to contribute towards finding natural solutions to climate change.
Aim: to study physicochemical and levels of selected metals in the soils of Abuja metropolis, Nigeria.

MATERIALS AND METHODS

Materials used for the physicochemical parameters determination included; electrical conductivity probe, calibrated pH meter, thermometer, calorimetric and Kjeldhal set ups among other materials.

Sampling Area

Abuja metropolis is a mega city comprising of Abuja city as federal capital city of Nigeria and its environs between the coordinates of Longitude 9.07°N and Latitude 7.40°E (Orisakwe *et al*., 2017). Asokoro forest is considered an unexploited land which is not used for farming or any significant anthropological activities as of the time of carrying out this work.

Sampling Method

Eleven (11) sampling points (five samples each from urban and sub urban areas respectively and also one sample from Asokoro Forest) in Abuja metropolis were selected at 15 cm soil depth using a grab sampling method and taken for air-drying for two weeks in order to preserve the texture and physicochemical parameters of the samples.

Sample Preparation

Samples were pretreated for clean up before analysis. Samples were air dried in the laboratory for 2 weeks and sieved with 100mm mesh one after another to get a uniform mass. The dried samples were taken to oven after the oven temperature was set at 105°C for about 12 hours each. The oven dry method was employed to take care of any microbial activity that might have taken place during air drying in the laboratory.

Determination of soil electrical conductivity

Soil electrical conductivity was measured using electrical conductivity probe on wet samples of urban and peri urban samples in the laboratory (Sun *et al*., 2017). 20.00g each of soil samples of urban and peri urban soils was taken and placed in a beaker containing 20.00cm^3 of distilled water, after total mixing, the conductor meter tip was placed in each container and stirring, until constant readings were observed. Average of three replicates of readings was taken as mean values for samples (Tongchai *et al*., 2021).

Determination of soil pH

pH values of urban and Asokoro forest soils were determined using a calibrated pH meter in the laboratory (Ticessea *et al.,* 2021). 20.00cm^3 of distilled water was added to about 20.00g sample of each of urban and Asokoro forest soils samples and mixed by stirring. The calibrated pH meter was inserted in each of the sample containers using stirring rod to stir the mixture simultaneously until pH meter displays constant reading. Measurement of pH involves detection of the charge in potential of a silver chloride combination electrode or glass electrodes using pH meter standardized against known buffer solution. Readings from each sample were taken in replicates of three and the average was taken as the mean value for each sample (Eom and Ahm, 2017).

Determination of soil SO_4

Soil suspension (1:5) was filtered after rapid shaking. Then about 50ml of solution was taken in a conical flask, its pH was made up to 4.5 to 5.00 by addition of 50% HCl solution. A few drops of methyl red indicator (0.1%) were added to the solution and finally excess amount of $BaCl_2$ solution (100g $BaCl_2$ in 1 litre solution) for some time (about 20 minutes). Finally, warmed after cooling, the precipitate was filtered through pre-weighed Whatman filter paper 42. Then the precipitate was washed by warm water and then the precipitate was oven-dried along with filter paper to obtain the weight of the precipitate of $BaSO_4$ (NEMI, 1978 and Indian Pharmacopoeia, 1996, 2016).

Determination of soil Cl

20.00g soil was suspended in 100 ml distilled water and then stirred mechanically (using orbital shaker) for about 1 hour at regular intervals. Then the suspension was filtered through Whatman No. 50 filter paper using Buchner funnel and vacuum pump. Then chloride content of 50ml of such filtered suspension is determined by titration against 0.02N $AgNO_3$ using 2.00ml of 5% $k_2Cr_2O_4$ (Mitshal *et al*., 2014).

Sample Digestion for Metals

Sieved soil samples were digested by adding 10mL each (from 1 mole of HCl and HNO_3) at 1:1:1 HCl-HNO_3-H_2O mixture to 20.00g of soil samples and heating at 98^{0}C for 1 hour. Heated samples were allowed to cool and then centrifuged at 3500xs for 10 minutes. An aliquot of the supernatant was pipetted and made to volume with 5% conc. HCl. Samples were kept in 50mL capacity polythene bottles for instrumental analysis (Oliveira, 2012).

RESULTS AND DISCUSSION

Urban and sub urban soil samples physicochemical and level of metals in Abuja soils are presented in the following tables. Tables 1a and 1b contain results of physicochemical as well as selected metals in Abuja urban soil samples. Tables 2a and 2b contain results of Pearson correlation coefficient of physicochemical and selected metals in both urban and sub urban soil samples.

Table 1a. Physicochemical and Level of Selected Metals in Abuja Urban Soil Samples

Parameters/Ions Sites	EC (µS/cm³)	pH	SO₄ (ppm)	Cl (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	As (ppm)
S1	101.94±0.65	7.09±0.01	58.05±0.05	65.05±0.01	1.78±0.03	0.20±0.01	0.10±0.001	0.27±0.00
S2	130.15±0.05	6.43±0.04	170.15±0.15	35.47±0.05	0.79±0.01	0.18±0.02	0.68±0.00	0.20±0.00
S3	41.20±0.20	6.72±0.28	10.15±0.15	25.03±0.04	1.21±0.01	0.27±0.02	0.76±0.00	0.13±0.01
S4	35.15±0.15	7.03±0.04	17.45±0.05	60.03±0.04	0.86±0.03	0.21±0.01	2.42±0.00	0.20±0.00
S5	32.05±0.05	6.92±0.02	28.25±0.05	55.05±0.07	1.08±0.00	0.19±0.01	0.31±0.01	0.21±0.00
Total(mean concentration of metals)					**5.72**	**1.12**	**4.27**	**1.01**
Standards:								
NESREA	**100**	**7.00-8.50**	**200**	**200**	**421**	**200**	**100**	**-**
WHO	**100**	**6.50-9.50**	**250**	**250**	**2800**	**300**	**1500**	**-**
Control	**31.20±0.28**	**6.45±0.45**	**24.65±0.07**	**35.02±0.02**	**2.49±0.01**	**0.31±0.01**	**1.73±0.01**	**0.16±0.01**

EC=Electrical conductivity, Control=Asokoro Forest, NESREA= National Environmental Safety, Regulation and Enforcement Agency, WHO= World Health Organisation.

Metal concentration in both Urban and Asokoro Forest soils in decreasing order: Zn>Cu>Mn>As

Table 1b. Physicochemical and Level of Selected Metals in Abuja Sub-Urban Soil Samples continued

Parameters/Ions Sites	EC (µS/cm³)	pH	SO₄ (ppm)	Cl (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	As (ppm)
S1	36.15±0.15	6.82±0.03	47.75±0.07	50.02±0.02	0.90±0.01	0.16±0.03	0.56±0.00	0.19±0.00
S2	50.15±0.15	7.01±0.01	64.05±0.07	45.42±0.11	0.60±0.00	0.17±0.01	0.84±0.00	0.22±0.01
S3	16.25±0.25	7.07±0.10	23.55±0.70	40.02±0.02	0.81±0.01	0.20±0.00	0.48±0.00	0.18±0.00
S4	84.10±0.10	7.11±0.14	35.05±0.07	50.03±0.04	0.79±0.01	0.03±0.00	0.10±0.01	0.27±0.00
S5	12.10±0.10	7.01±0.01	61.15±0.07	55.02±0.03	1.62±0.02	0.86±0.01	0..26±0.06	0.31±0.01
Total(mean concentration)					**4.72**	**1.42**	**2.25**	**1.17**

Metal concentration in sub urban soils in decreasing order: Zn>Cu>Mn>As

Table 2a. Pearson Correlations Coefficients of Physicochemical and Selected Metals in Abuja Urban Soils

	EC	pH	SO_4	Cl	Zn	Mn	Cu	As
EC	I	-0.3290	0.1087	0.0252	0.0023	-0.0408	0.1751 0.3150	-
pH		I	0.0129	0.2799	0.2354	0.1956	0.1487	0.2337
SO_4			I	0.2834	0.1662	0.0382	0.0633	0.2330
Cl				I	0.1182	0.0031	0.0580	0.3145
Zn					I	0.0011	0.2514	0.0104
Mn						I	0.0021	0.0002
Cu							I	0.003
As								I

EC=Electrical conductivity

Table 2b. Pearson Correlations Coefficients of Physicochemical and Selected Metals in Sub Urban Soils continued

	EC	pH	SO_4	Cl	Zn	Mn	Cu	As
EC	I	-0.6211	-0.1066	-0.0864	--0.0810	0.2377	0.0142	0.0205
pH		I	-0.3933	-0.1801	-0.3293	0.4066	0.1326	0.1325
SO_4			I	0.2603	-0.2964	0.2633	0.3934	0.0616
Cl				I	0.4327	-0.3350	0.5944	0.2712
Zn					I	0.0368	0.3120	0.3120
Mn						I	0.0370	0.0142
Cu							I	0.1120
As								I

A comparison of physicochemical and selected metals in both Abuja urban, sub-urban with Asokoro Forest as control is discussed here. Urban S1 had value of 196.98±0.08μS/cm^3 electrical conductivity higher than sub urban S1 with value of 36.15±0.15 μS/cm^3 this could be due to urban soil continuum as observed by Zhang *et al*., (2023). Urban S2 had value of 130.15±0.05 higher than what was obtained in sub urban S2 with value of 50.15μS/cm^3, this could be due to increase in ion concentration at the urban S2 site; this conforms to the findings of Kamsali *et al*.,(2011).Urban S3 had value of 41.20±0.20 higher than what was obtained in sub urban S3 with value of 16.25±0.25, this could be due to the presence of a recreational park near urban S3; this is in conformity to the findings of Kunakh *et al*., (2018). Urban S4 had value of 35.15±0.15 lower than that of sub urban S3 with a value of 84.15±0.10, this could be due to rural settings at sub urban S4 area; this did not conform to the findings of Sodiya, (2023). Urban S5 had value of 32.05±0.05 higher than sub urban S5 with value of 28.05±0.01 this could be due to urban traffic near urban S5; this conforms to the findings of Abderrahmane *et al*., (2021).

Urban S1 had pH value of 7.09±0.01 higher than sub urban S1 with value of 6.82±0.03, this could be due to sub-urban soils higher alkalinity; this corresponds to the findings of Barnes, (2018). Urban S2 had value of 6.43±0.04 lower than sub urban S2 with value of 7.01±0.01, which could be due to regional resident activities; this conforms to the submission of Mao *et al*., (2014). Urban S3 had 6.72±0.28 which was more alkaline than sub urban S3 with value of 7.05±0.02, this could be due to high anthropogenic activities near urban S3 site, this agrees with the findings of Li *et al*., (2013). Urban S5 had value of 6.35±0.35 more alkaline than sub urban S3 having value of 7.01±0.01, this could be due to accumulation of earthy materials as a result of anthropogenic activities at urban S3 site; this conforms to the findings of Funquim, (2022). Urban S4 had value of 7.20±0.20 having equal value with sub urban S4, this could be due to similar anthropogenic activities, this does not conform to the findings of Adedeji *et al*., (2019). Urban S5 had value of 6.35±0.35 more alkaline than sub urban S5 with 7.01±0.01, which could be due to high accumulation of earthy materials at urban S5; this conforms to the findings of Ariori *et al*., (2023).

Urban S1 had SO_4 value of 58.05±0.05ppm higher than in sub urban S1 with 47.75±0.07; this could be due to high deposition of cosmetics and food residues at urban S1; this conforms to the findings of Dahiri *et al*., (2021). Urban S2 had value of 17.15±0.15 lower than at sub urban S2 with 64.05±0.0.07, this could be due to the presence of cosmetics, pharmaceutical industries and warehouses at sub urban S2: this conforms to the findings of California Air Resources Board, CARB, (2020). Urban S3 had 10.15±0.15 lower than at sub urban S3 site with 23.55±0.70, could be due to higher anthropogenic activities at sub urban S3 site; this does not conform to the findings of Lee *et al*., (2021). Urban S4 had 170.45±0.05 higher than in sub urban S4 with 35.05±0.07; could be attributed to high presence vehicular movement, food remnants and other anthropogenic activities at urban S4 which is a motor park; this conforms to the findings of Bruce, (2019). Urban S5 had value of28.25±0.05 lower than that of sub urban S5 with 61.15±0.07 could due to high deposition of remnants of food and cosmetic materials at sub urban S5 site; this conforms to the findings of Akhtar, *et al*., (2021).

Urban S1 had Cl value of 65.05±0.01ppm higher than in sub urban S1 with 50.02±0.02; this b could be due to salt in food remnants and atmospheric deposition of chloride at urban S1 being a passenger spot; this conforms to the findings of Conrad-Rooney *et al*., (2023). Urban S2 had value of 35.47±0.005 lower than in sub urban S2 with 45.42±0.11; could be as a result of presence of food warehouses around sub urban S2 site; this conforms to the findings of Brugnone *et al*., (2023). Urban S3 had value of 25.03±0.04, lower than in sub urban S3 with 40.02±0.02; this could be due to higher vehicular and anthropological activities at sub urban S3; this does not conform to the findings of Gutchess *et al*., (2016). Urban S4 had value of 60.03±0.07 higher than in sub urban S4 with 50.03±0.04, could be due to higher atmospheric deposition of Cl at urban S4; this is in accordance with the findings of Vega *et al*., (2023). Urban S5 had value of 55.05±0.07 which was not significantly higher than in sub urban S5 with 55.02±0.03; this could be due to vehicular traffic and asphalt pavements at both sites; this agrees with the findings of Broomandi *et al*., (2022).

Urban S1 had Zn mean concentration of 1.78±0.03ppm higher than what was obtained at sub urban S1 site, which was 0.90±0.007, could be due to atmospheric deposition, runoff debris and anthropological activities at urban S1 area; this is in conformity with the findings of Pardo, (2021). Urban S2 had mean concentration of 0.79±0.01 higher than in sub urban S1 which had 0.60±0.002, this could be due to closeness of urban S1 site to auto spare parts market; but this is not in accordance with the findings of Andronikov *et al*., (2021). Urban S3 had mean concentration of 1.21±0.007 higher than the concentration in sub urban S3 which had 0.81±0.002, this could be due to rapid urbanisation and atmospheric deposition of Zn in sub urban site; this is in conformity with the findings of Shen *et al*., (2016). Urban S4 had mean concentration of 0.86±0.01 higher than that of Karmo site I which is 0.79±0.001, could be due to high human and vehicular movements at urban S4 site; this is in conformity with the findings of Okereke *et al*., (2019). Urban S5 had mean concentration of 1.08±0.007 lower than that of sub urban S5 which had mean concentration of 1.62±0.002; this could be due to pollution and organic matter content in sub urban S4; this does not conform to the findings of Dauda and Odoh, (2013).

Urban S1 had Mn mean concentration of 0.19±0.01ppm higher than what was obtained at sub urban S1 site with 0.16±0.03, could be due to deposition of food debris and atmospheric deposition of Mn at urban S1 site; this conforms to the findings of Gunawardena *et al*., (2015). Urban S2 had mean concentration of 0.15±0.02 lower than what was obtained at sub urban S2 site which was 0.17±0.01, this could be due to industrial emission at sub urban S2 area; this is in conformity with the findings of Daleker *et al*., (2023). Urban S3 had mean concentration of 0.27±0.02 higher than what was obtained at sub urban site which was 0.03±0.002, this could be due to proximity of the site to an urban market which is a hotspot for metal deposition; this is in conformity with the findings of Uebari and Boisa, (2019). Urban S4 had mean concentration of 0.21±0.007 lower than sub urban S4 mean concentration of 0.03±0.002, could be due to proximity to a highway, human and vehicular activities at sub urban S4 area; this does not conform to the findings of Magaji and Mallo, (2020). Urban S5 had mean concentration of 0.19±0.01 higher than mean value of sub urban S5 which was 0.16±0.03, this could be due to presence of a taxi rank motor park which is a hot spot for metal deposition; this is in conformity with the findings of Muze *et al*., (2020).

Urban S1 had Cu mean concentration of 0.10±0.007ppm lower than what was obtained at sub urban S1 site with 0.56±0.001, could be due to electronic wastes at sub urban S1 area this is not in conformity with the findings of Xing *et al*., (2020). Urban S2 had mean concentration of 0.68±0.003 lower than the mean value at sub urban S2 site having mean value of 0.84±0.007, this could be due to industrial emissions and wastes at sub urban S2 area; this conforms to the findings of Stanojevic, (2021). Urban S3 had mean concentration of 0.76±0.007 higher than sub urban S3 with 0.48±0.01, could be due to proximity of urban S3 to an urban market; this is in conformity with the findings of Salas *et al*., (2013). Urban S4 had mean concentration of 2.42±0.002 higher than in sub urban S4 with 0.10±0.005, could be due to vehicular movements and other anthropogenic activities at urban S4 site; this conforms to the findings of Adamiec *et al*., (2016). Urban S5 had mean concentration of 0.31±0.01 higher than what was obtained at sub urban S5 site having mean value of 0.26±0.06, could be due anthropogenic activities at urban S5 site; this conforms to the findings of Dusenmungu *et al*., (2022).

Urban S1 had As mean concentration of 0.27±0.001ppm, higher than what was obtained at sub urban S1 site having 0.19±0.001; this could be due to atmospheric deposition at urban S1 site; this conforms to the findings of Karavyava *et al*., (2022).Urban S2 had mean concentration of 0.20±0.003 lower than what was obtained at sub urban S2 site having 0.22±0.006, could be due to industrial emission at sub urban S2 site; this is in conformity with the findings of Chen *et al*., (2015). Urban S3 had mean concentration of 0.13±0.007 lower than what was obtained at sub urban site with mean value of 0.27±0.004, this could be due to atmospheric deposition of As at sub urban S3 area; this conforms to the findings of Ye *et al*., (2021). Urban S4 had mean concentration of 0.20±0.0007 lower than mean concentration at sub urban S4 site having mean value of 0.27±0.004, could be due to urban atmospheric deposition at urban S4 site; this is in conformity with the findings of Irunde *et al*., (2022). Urban S5 had mean concentration of 0.21±0.003 lower than mean value obtained at Lugbe site I having mean value of 0.31±.007; this could be due to vehicular movement near sub urban S5 site; this does not conform to the findings of Fillippeli *et al*., (2019).

Correlations were calculated for both physicochemical parameters and percentage mobility of metals under study in Abuja soils. Positive correlation between physicochemical and percentage mobility means an increase in the value of one will lead to a corresponding increase in the other which implies a strong relationships between them, whereas, negative correlation means that an increase in the mean value of one will lead to a decrease of the same in the other which does not imply strong relationships between entities, this is in conformity with the findings of Nikolas, (2019).

In Abuja urban soil samples, there were positive correlations between EC and SO_4 as +0.1087 Cu and EC as +0.1751, pH and Mn as +0.1956, As and pH as + 0.2337 respectively and there were negative correlations between pH and EC as -0.3290 and between As and EC as -0.3150 respectively. In sub urban samples there were positive correlations between EC and Mn as +0.2377, pH and Mn as +0.4066, Cl and Zn as 0.4327, Cu and Cl as +0.5944 respectively and there were negative correlations between EC and pH as -0.6211, pH and SO_4 as -0.3933 respectively.

Conclusion

Physicochemical parameters and selected metals in Abuja soils were studied and results obtained. Most of the physicochemical as well as metals availability are dependent on anthropological activities including vehicular movement, industrial activities as well as atmospheric deposition in the soils of Abuja Metropolis. SO_4 was found to be having highest concentrations in Abuja soils and Cl in Asokoro Forest. While SO_4 can have reflective properties to deflect sunrays thereby reducing global warming, it can increase acid in the Metropolis. Excess Cl in Asokoro Forest can be devastating to plants and their growth. Metal concentration sequence in both Abuja urban soils and Asokoro Forest was found to be: Zn>Cu>Mn>As and in sub urban soils was: Zn>Cu>Mn>As. Although Zn and Cu in required amounts are beneficial to plant growth and human health, their excess can be detrimental to humans, plants and the environment.

Based on the high concentration of Zn in the above sequences especially in Asokoro Forest which was a zone with less human activities, it can be attested that Abuja Metropolis is sitting on Zn deposits. Excess Zn in Abuja soils reduces the rate of photosynthesis and other phytoactivities in plants, thereby increasing CO_2 in the atmosphere causing global warming. Similarly, excess Cu can interfere in the decomposition and other microbial activities in the soils, thereby affecting soil balance. The results showed the negative effect of anthropological activities on both urban and sub-urban soils which can cause global warming eventually. More attention should be given to periodic environmental risk assessments of Abuja soils in order to checkmate the rising physicochemical and metal build up in the metropolis.

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CONFLICT OF INTEREST

There is no conflict of interest in this work.

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