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Heavy Metal Concentration in the Soil and Sediment of Kotur Industrial Area Hyderabad, India

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Authors' contributions

This work was carried out in collaboration between all authors. Author NNM designed the study while author EIO wrote the first draft of the manuscript including the literature searches. Authors RKM and KAK managed the analysis and interpretation. The co-authors supervised the corresponding author during the research work.

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ABSTRACT

Heavy metal accumulations in the environment are major sources of pollution and contamination. Soil samples were collected from Kotur industrial area and analysed for heavy metal concentration such as Vanadium, Chromium, Nickel, Cobalt, Copper, Zinc, Barium, Lead, Rubidium, Strontium, and Zircon using inductively coupled mass spectrometer (ICP-MS) instrument. The ranges of concentration obtained for these metals are V (60.96-111 mg/kg), Cr (68.22–141.03 mg/kg), Ni (33.18-68.74 mg/kg), Co (10.16-17.67 mg/kg), Cu (26.35-47.59 mg/kg), Zn (49.95-183.23 mg/kg) and Pb (30.98-79.91 mg/kg). The analytical data revealed concentration above the background values. The assessment of the contamination level of the area was based on geoacummulation index (Igeo), enrichment factor (EF) and anthropogenic input. The result also showed enrichment associated with anthropogenic input for the heavy metals such as Cr, Ni, Pb, and Cu in the study area. The calculated Igeo values ranges from 1.19 to 1.43. The EF values for Cr, Ni and Pb range from 0.80 to 3.08, 0.68 to 3.07 and 0.82 to 20.6 respectively indicating moderate enrichment. The coefficient values of 0.90, 0.66, 0.62 and 0.58 observed between V and Co, Cu and between Pb with Y and Zr indicate input from similar sources.

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1. INTRODUCTION

Industrialization and urbanization have provided livelihood and opportunities to millions in urban, semi-urban and rural areas but not without implications. These result in the generation of volumes of solid wastes that are poorly disposed especially in developing countries. Soil contamination due to indiscriminate waste disposal from industries is prominent in high population areas where every bit of the land is put into use [1]. Although the complex nature of soil tends to pose serious problems [2-4] they are therefore regarded as the ultimate sink for metals. Soils are considered contaminated when its chemical properties are altered in any form. This alteration is often associated with the release of waste into the environment. Input of metals and synthetic chemicals into the environment results in environmental pollution. The chemicals in the terrestrial environment pose significant risk to the quality of soils, plants, natural waters, and human health [5-9]. While some metals such as Zn, Cu, and Sr are essential elements for normal growth of plants and living organisms, their high concentration in the environment are usually toxic. Others such as Pb or Cr, which may be tolerated by the ecosystem in low concentration however, become harmful in higher concentrations [10,11]. The effects of heavy metal contamination on the environment and its remediation have been extensively studied by [12-15]. The concentration of heavy metals such as Pb, Cd, Cr, and Zn in uncontaminated soil range from 2–300, 0.01-2.7, 5-1500, 1-900 mg/kg respectively [16].

The Kotur industrial area host many industries such as pharmaceutical, battery, steel, metal and alloy, agro-chemicals, paint, paper, oil etc. The wastes generated by these industries are indiscriminately disposed on open spaces due to lack of waste management facilities. The research is aimed at determining the level of contamination of the area with respect to the background concentration of the heavy metals in the area. In the present study, the concentration of V, Cr, Ni, Co, Cu, Zn, Ba, Pb, Rb, Sr, Y and Zr were assessed using ICP-MS with a view of determining their sources to the environment. The study is also aimed at evaluating anthropogenic contribution of environmental contamination of the area using geoaccumulation index (Igeo), enrichment factor (EF) and anthropogenic input tools.

1.1 Geology and Hydrogeology of the Study Area

The study area lies within Latitude 17º05'N to 17º10'N and Longitude 78º15'E to 78º20'E in the southern part of Hyderabad, India. It is characterized by an undulated topography with an elevation of 547 to 610 m above msl. The geology of the area consist of granite (Archean) that are hard-massive to foliated and well-jointed, characterized by pink and grey colours. The soil cover is of well-developed residual soil of weathered granite that is fertile and supports agricultural activities. The groundwater occurs at a depth of about 30 m in the zone of the weathered granite, decomposed granite and fractured bedrocks. The groundwater resources of the area are also significant for irrigation farming which is the major source of livelihood for the rural dwellers.

2. MATERIALS AND METHODS

Eleven soil samples were collected from Kotur industrial area in self locking plastic bags using hand trowel at a depth of 5 cm (Fig.1). 0.05 g of each of the samples was digested by open digestion method following standard practice for ICP-MS analysis [17]. The certified SO-1 standard analysed along with the samples for accuracy are shown in Table 1.

In the present study, PerkinElmer Sciex ELAN DRC II ICP-MS instrument was used for the analysis of heavy metals and the results presented in Table 2. Geoaccumulation index (Igeo), enrichment factor (EF) and anthropogenic input were applied to assess the heavy metal contamination in the soils.

2.1 Geoaccumulation Index (Igeo)

This technique has been employed by many authors [18-22] to assess soil contamination especially in industrial areas. The principle determines contamination by comparing current metal contents with pre-industrial concentration and was initially used in bottom sediment contamination studies [23]. The value of the geoaccumulation index is described by the following equation:

$$I_{geo} = Log_2 C_n / 1.5 B_n$$

For this study, the modified calculation of the above equation by [24] was adopted where Cn denotes the concentration of a given element in the analysed soil samples, and Bn denotes the concentration of the element in the earth's crust [25]. The obtained I_{geo} values were interpreted using the following ranges stated by [20].

$I_{geo} \le 0$ practically uncontaminated,
$0 < I_{geo} < 1$ uncontaminated to moderately contaminated,
$1 < I_{geo} < 2$ moderately contaminated,
$2 < I_{geo} < 3$ moderately to heavily contaminated,
$3 < I_{geo} < 4$ heavily contaminated,
$4 < I_{geo} < 5$ heavily to very heavily contaminated and
$I_{geo} \ge 5$ very heavily contaminated.

2.2 Enrichment Factor (EF)

The values of EF were calculated using the modified formula given by [24] based on the [26] equation as shown below

$$EF = \frac{C_n(sample)/C_{ref}(sample)}{B_n(background)/B_{ref}(background)}$$

An element is regarded as a reference element if it is of low occurrence variability and is present in the environment in trace amounts [27-29,20,21]. The most common reference elements are Sc, Zr, Mn, Al and Fe [17]. For the purpose of this study, Zr was used as the reference element because of its stability. Zr has been widely used in geochemical studies of mineral weathering as a stable lithogenic element or for assessment of depletion of more reactive heavy metals in sediments [30-32]. It is also chosen to reduce the scatter data and allow a precise definition to background value as normalizer. The B_{ref} value of Zr used for the calculation of the enrichment factor is 190 mg/kg [25].

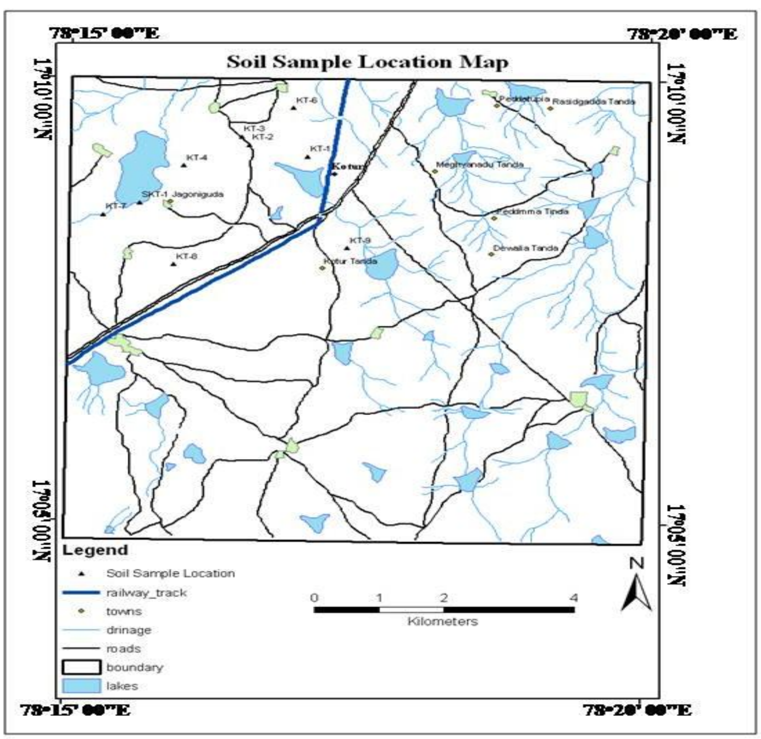

Fig. 1. Map of the study area showing soil sample location

Table 1. Analytical values of SO-1 standard (mg/kg)

V	Cr	Ni	Co	Cu	Zn	Ba	Pb	Rb	Sr	Y	Zr
113	170	92	29	61	140	870	20	14	331	24	84

Five contamination categories were recognized on the basis of the enrichment factor [33].

EF < 2 depletion to minimal enrichment,
EF = 2 - 5 moderate enrichment,
EF = 5 - 20 significant enrichment,
EF = 20 - 40 very high enrichment,
EF > 40 extremely high enrichment.

The enrichment factor due to its wild acceptability is a relatively convenient tool for the assessment of enrichment degree and comparing the contamination of different environmental media [20,22], although certain shortcomings abound [29].

2.3 Anthropogenic Input

An estimation of the anthropogenic input to the soils of the study area in relation to the natural background concentrations was calculated. The background values of the metals were adopted from [25]. The percentage contributions of anthropogenic impact on metal concentration were calculated to determine influence of industrial and other human activities in the area.

3. RESULTS AND DISCUSSION

The concentration and statistical result of the heavy metal analysis are presented in Table 2. Some of the metals have concentration above the acceptable limit indicating influence of the industrial activities within the area.

The concentration of Chromium in the soil of the study area varied from 68.22 to 141.03 mg/kg with an average value of 102.05 mg/kg. Chromium concentration in the soil samples are high and have values above Canadian Soil Quality Guideline (CSQG). The high concentration of this heavy metal may be attributed to the anthropogenic activities resulting from various industries in the area. Copper is an essential micro-nutrient significant for both animals and plant growth although, health problems are associated with injection of its high dose [34,35,21]. Copper is neither magnified in the body nor bio-accumulated in the food chain [36]. The value of copper concentration in the soil samples range from 26.35 to 47.59 mg/kg. The concentration of lead in the present study varied from 30.98 to 79.91 mg/kg with an average of 49.43 mg/kg. Pb value for surface soil has been estimated to be 25 mg/kg and levels above this suggest an anthropogenic influence [36]. Pb has the least mobility potential among the toxic metals due to the binding of the metal to organic matter [37-39].

The concentration of Vanadium varied from 60.96 to 111 mg/kg with an average value of 85.41ppm. The normal distribution of Vanadium in soils is 100 mg/kg [40,41]. The most common application of Nickel is in steel and other metal products. The concentration of nickel in the soil samples range from 33.18 to 68.74 mg/kg with an average value of 51.31 mg/kg exceeding the level recommended by CSQG for uncontaminated soils. The range of the concentration of Zinc obtained for the present study is from 49.95 to 183.23 mg/kg. Industrial and agricultural activities are the main sources of Zinc pollution [42]. The average concentration of Barium for the present study is 654.55 mg/kg. The concentration of Barium ranges from 497.79 to 835.92 mg/kg in the soil samples. The values are below CSQG suggesting geogenic source. The values of Rubidium and Cobalt in the soil samples, varied from 14.96 to 155.25 mg/kg and 10.16 to 17.69 mg/kg respectively. The average value of Strontium concentration in the soil is 188.24 mg/kg. The minimum and maximum values of Sr are 108.58 mg/kg and 444.5 mg/kg respectively. Most of Zr minerals accumulate as placer deposits, small quantity takes part in sedimentation and absorbed by clay minerals [43]. The concentration of Zr in the soil samples ranges from 204.71 to 649.89 mg/kg with an average value of 366.31 mg/kg.

The obtained I_{geo} values presented in Table 3 were interpreted using the ranges stated by [20]. Based on the six classes of geoaccumulation index (Igeo), 41.67% of the samples fell into class 1 of the Mullars I_{geo} classification of uncontaminated to moderately contaminated soil with values ranging from 0.24 to 0.78. The I_{geo} values ranging from 1.19 to 1.43 representing 33.33% of the total sample fell under class 2 of the classification depicting moderately contaminated soils Fig. 2. The rest fell into class 0 practically uncontaminated. Cr showed the highest I_{geo} value of 1.43 and may be attributed to the presence of paper, paint and metal alloy industries in the area.

Table 2. Metal concentration of the soil samples in mg/kg and the reference values (Taylor and Meclennan, 1995 [26])

Samples	V	Cr	Co	Ni	Cu	Zn	Ba	Pb	Rb	Sr	Y	Zr
KT-1	66.52	95.23	11.21	44.41	34.62	98.49	835.9	51.89	16.73	207.25	23.65	278.8
KT-2	111.0	120.9	15.59	68.74	46.52	49.95	708.5	30.98	16.99	137.3	18.53	213.0
KT-3	79.49	119.5	12.43	44.45	44.58	138.6	689.0	49.78	16.86	141.2	18.96	371.6
KT-4	76.23	68.22	11.68	33.18	26.35	70.82	497.8	42.63	17.37	108.6	30.93	464.2
KT-5	99.15	130.4	17.66	67.80	42.78	101.6	735.7	40.27	15.71	176.5	25.55	260.7
KT-6	75.62	117.6	11.38	62.80	37.71	106.0	723.2	56.17	19.38	112.9	46.52	649.9
KT-7	60.96	141.0	10.16	62.64	32.18	74.02	666.6	38.08	14.96	444.5	21.47	312.0
KT-8	81.35	78.29	11.39	45.47	33.67	123.5	570.3	79.91	17.61	222.8	38.78	486.8
KT-9	99.81	91.02	14.36	47.02	47.59	183.2	620.4	61.41	17.83	196.2	28.61	390.7
KTS-1	81.78	80.60	12.67	37.38	36.32	73.46	647.3	48.24	20.85	137.6	27.13	397.0
KTSD-1	107.7	79.74	16.14	50.54	37.83	83.53	505.5	44.39	155.3	185.9	29.77	204.7
Min	60.96	68.22	10.16	33.18	26.35	49.95	497.8	30.98	14.96	108.6	18.53	204.7
Max	111.0	141.0	17.66	68.74	47.59	183.2	835.9	79.91	155.3	444.5	46.52	649.9
Average	85.41	102.0	13.15	51.31	38.20	100.3	654.5	49.43	29.96	188.2	28.17	366.3
STD	16.57	24.62	2.420	12.28	6.580	37.44	101.8	13.23	41.59	93.18	8.430	133.2
Ref. Val	60.00	35.00	10.00	20.00	20.00	71.00	550.0	20.00	-	-	-	190.0

Table 3. Igeo values for the analysed heavy metals

Samples	V	Cr	Co	Ni	Cu	Zn	Ba	Pb	Rb	Sr	Y	Zr
KT-1	-0.44	0.86	-0.42	0.57	-0.12	-0.11	0.02	0.79	-3.33	-1.34	-0.48	-0.03
KT-2	0.30	1.20	0.06	1.20	0.31	-1.09	-0.22	0.05	-3.31	-1.93	-0.83	-0.42
KT-3	-0.18	1.19	-0.27	0.57	0.25	0.38	-0.26	0.73	-3.32	-1.89	-0.80	0.38
KT-4	-0.24	0.38	-0.36	0.15	-0.51	-0.59	-0.73	0.51	-3.27	-2.27	-0.09	0.70
KT-5	0.14	1.31	0.24	1.18	0.19	-0.07	-0.17	0.42	-3.42	-1.57	-0.37	-0.13
KT-6	-0.25	1.16	-0.40	1.07	0.01	-0.01	-0.19	0.90	-3.12	-2.22	0.50	1.19
KT-7	-0.56	1.43	-0.56	1.06	-0.22	-0.52	-0.31	0.34	-3.49	-0.24	-0.62	0.13
KT-8	-0.15	0.58	-0.40	0.60	-0.16	0.21	-0.53	1.41	-3.25	-1.24	0.23	0.77
KT-9	0.15	0.79	-0.06	0.65	0.34	0.78	-0.41	1.03	-3.24	-1.42	-0.21	0.46
KTS-1	-0.14	0.62	-0.24	0.32	-0.05	-0.54	-0.35	0.69	-3.01	-1.93	-0.28	0.46
KTSD-1	0.26	0.60	0.11	0.75	0.01	-0.35	-0.71	0.57	-0.11	-1.50	-0.15	-0.48
Min	-0.56	0.38	-0.56	0.15	-0.51	-1.09	-0.73	0.05	-3.49	-2.27	-0.83	-0.48
Max	0.30	1.43	0.24	1.20	0.34	0.78	0.02	1.41	-0.11	-0.24	0.50	1.19

The result of the calculated enrichment factor (EF) is shown in Fig. 3. The metals V, Co, Cu, Zn, Ba, Rb, Sr and Y show depletion to minimal enrichment. Minimum EF values range from 0.05 to 0.44 and maximum EF values range from 0.77 to 1.67. The EF values for Cr, Ni and Pb range from 0.80 to 3.08, 0.68 to 3.07 and 0.82 to 20.6 respectively indicating moderate enrichment. Since only about 27% of the total sample fell within the category of moderate enrichment, the study may serve as a guide for the monitoring of the industrial activities in the area been a relatively new industrial layout without much influence on the environment yet.

The percentage anthropogenic contribution to the contamination of the soil of the study area is presented in Fig. 4. The percentage input for Cr, Ni and Pb are 66%, 61% and 60% respectively confirming the earlier results of EF for these metals. While Zn, V and Cu revealed an input of 29%, 30% and 35%, values of 24%, 22% and 16% were obtained for Co, Y and Ba. The above results indicate that the concentration of all the analysed heavy metals have been influenced by anthropogenic activities.

3.1 Interelemental Correlation

Correlation matrix of the heavy metals indicating the relationships between them are shown in Table 4. At a significant level of $\rho < 0.05$, good relationship was observed between the analyzed metals. Strong positive correlation with a coefficient value of 0.90 and 0.66 was obtained between V with Co and Cu. Positive correlation was also observed between Ni and Ba. Pb correlated positively with Y and Zr with a coefficient of 0.62 and 0.58 respectively while a coefficient of 0.80 was observed between Zr with Y.

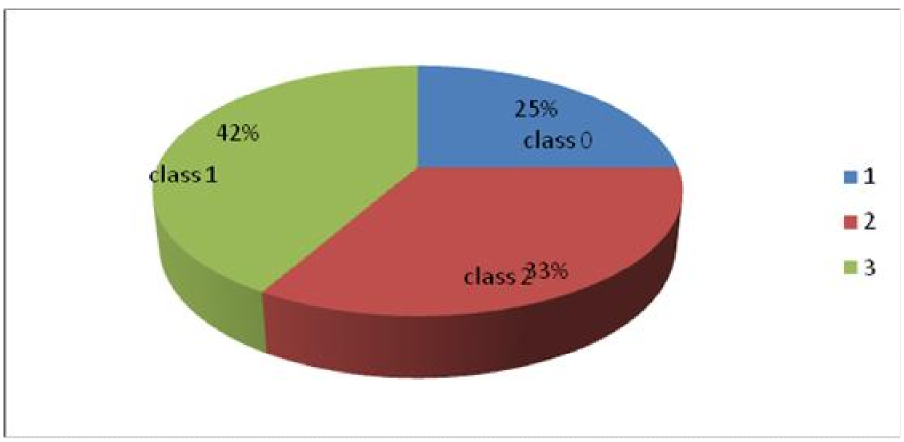

Fig. 2. Percentage distribution of the I_{geo} values among the six classes

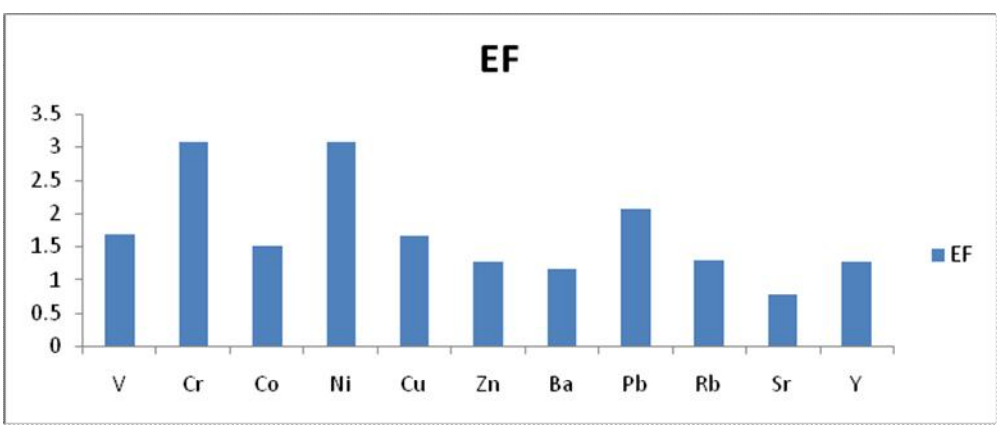

Fig. 3. A plot of the EF max obtained in the study area

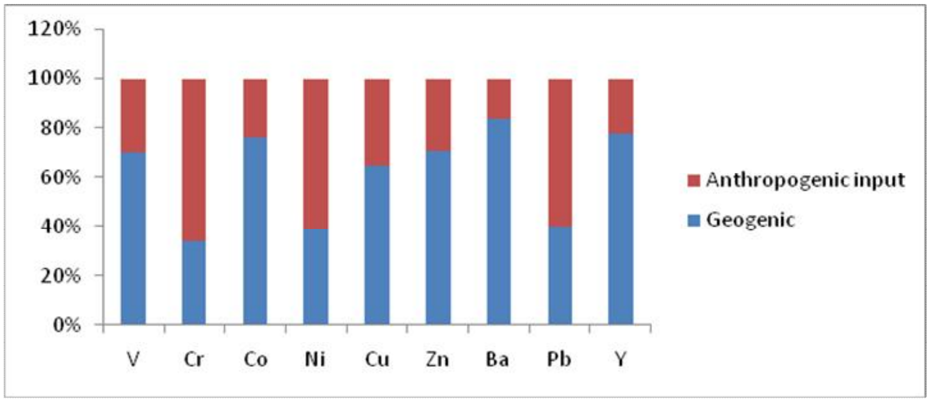

Fig. 4. Percentage anthropogenic input to the metal contamination of the area

Table 4. Correlation analysis of heavy metals in soil samples

	V	Cr	Ni	Co	Cu	Zn	Ba	Pb	Rb	Sr	Y	Zr
V	1											
Cr	-0.09	1.00										
Ni	0.03	0.81	1.00									
Co	0.90	0.09	0.39	1.00								
Cu	0.66	0.39	0.44	0.62	1.00							
Zn	0.04	-0.07	-0.02	-0.01	0.44	1.00						
Ba	-0.24	0.61	0.43	-0.06	0.34	0.03	1.00					
Pb	-0.20	-0.44	-0.39	-0.35	-0.09	0.66	-0.16	1.00				
Rb	0.45	-0.32	-0.04	0.41	-0.02	-0.15	-0.49	-0.11	1.00			
Sr	-0.44	0.41	0.27	-0.34	0.23	-0.04	0.06	-0.05	-0.03	1.00		
Y	-0.13	-0.35	-0.08	-0.24	-0.32	0.20	-0.26	0.62	0.08	-0.26	1.00	
Zr	-0.45	-0.19	-0.24	-0.57	-0.31	0.30	-0.12	0.58	-0.38	-0.26	0.80	1.00

The significant positive correlations among the metals reveal their common sources in the soil samples.

4. CONCLUSION

The study, displayed evidence of alteration in the background concentration of heavy metals in the environment. The variation in the heavy metal concentration is attributed to poor waste disposal from the industrial layout. The high percentage of Cr, Ni and Pb obtained through anthropogenic input and enrichment factor calculations show that these metals originated from the industries. Although the level of concentration of some of the heavy metals were above international accepted standard, the study generally disclosed evidence of relatively moderate contamination possibly due to the short period of activities in the area. The increased levels of these metals in the soil will consequently increase their concentration in surface and groundwater. The concentration if not check will soon reach a toxic level harmful to both humans and the ecosystem. It is suggested that the study serves as a database for future studies and guide for the monitoring of the activities of the industries in the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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