Determination of local background and baseline values of elements within the soils of the Birimian Terrain of the Wassa Area of Southwest Ghana

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ABSTRACT
This study establishes the local background and baseline values of elements in surface soils in Wassa area underlain by Birimian rocks using probability Q–Q plots. In this study, a total of 2868 soil samples were collected. The chemical elements in these samples were analysed by XRF technique. The results from the analysis were processed following Papastergios and Karim methods that normalized and transformed the data after which a best of fit is estimated to determine the background and baseline values. The method excludes the outliers at the extremities from the transformed data until the distribution follows a straight line. The method yielded the following background values in this study: 6.41 mg/kg for As, 52.55 mg/kg for Cr, 9.89 mg/kg for Pb, 10.21 mg/kg for Co and 17.18 mg/kg for Ni. The calculated baseline values were also 13.2 mg/kg, 80.7 mg/kg, 6.7 mg/kg, 6.4 mg/kg and 8.7 mg/kg for As, Cr, Pb, Co and Ni, respectively. The departure between the locally calculated background and baseline values of elements relative to worldwide accepted background and baseline values suggests the relevance to conduct such studies for the various geological provinces in the country as a vital step to properly and effectively manage and sustain the environment against environmental health diseases.

Introduction
The elements in soils have been identified as vital components of the environment because they can be hazardous or essential to human health. Translocation of these elements in soils to food chains may impact on human health. Monitoring and managing the impacts of the natural environment on public health require the establishment of environmental background and baseline values as this will guide in outlining the environmental risk areas. The background values provide a guide to ascertain the presence of anthropogenic effects that could lead to hazardous or beneficial consequences. In environmental geochemistry and health, the background is considered as the natural concentration in environmental material devoid of human influences. It is distinguished from environmental baseline values that refer to the natural variations in the concentration of an element in the surface environment, at a determined place and time. This concept includes natural geographic concentrations (background level) and the diffuse anthropogenic contribution in soils (Kobierski & Dabkowska-Naskret, 2012). The impact of this may be deleterious or beneficial.

It is unclear if Ghana has its own background and baseline values to monitor and manage the impact of the natural environment on public health issues. The available testimonies in this discipline suggest otherwise because earth science and public health researchers either use World Health Organization (WHO) values or worldwide acceptable values instead of locally established background and baseline values. Background values are determined by the composition of the underlying rock as well as the weathering processes prevalent in the area and are considered as the normal values of potentially polluting substances present in natural soils without human influence (Matschullat, Ottenstein, & Reimann, 2000). It has been argued that rocks have a large influence on element contents in soils, with concentrations sometimes lower and above critical values (Salonen & Korkka-Niemi, 2007). However, it is almost impossible to establish natural background levels, i.e., the geochemical composition of virgin soils, since atmospheric deposition can contaminate soils with certain trace elements (Cicchella et al., 2005, Albanese, 2014). But from Riemann and de Caritat (2005) human activity is a key determinant of the level of element concentrations in soils. Ordinarily, places such as industrial and residential areas are often considered as environments at higher risk of anthropogenic influences on elemental soil concentrations. Relatively, Alloway (2013) recognized less modified and undisturbed areas such as forests and subsistent farmlands are mainly considered as close to pristine zones with minimal pollution.

Based on Alloway’s assertion, the establishment of local background and baseline values for different
geological domains is critical due to the variations in the modal composition of rocks from place to place and the numerous environmental activities. The detection of the human-induced contamination in an environment is properly assessed using the baseline value, which is uncommon in Ghana. The most commonly used method of determining human influences on soils in works done in Ghana relies on the use of continental crustal averages and worldwide accepted values, which have been proven to be problematic (Arhin, Mouri, & Kazapoe, 2017). The present spate of illegal mining and infrastructural developments coupled with population growth in Ghana makes it challenging to identify undisturbed soils or virgin soils. Example, illegal mining and logging, conversion of farmlands to residential areas tend to suggest the destruction of precinct lands hence calculated local background values if not expressed as a range may be problematic. The variable nature of element concentrations due to underlying geology, geological processes and anthropogenic chemical contribution due to human activities results in variable element contents. The present research sees the inappropriateness of just using the natural concentrations to establish the pollution status at a place because of the numerous processes influencing the landscape modifications. Rather, both background and baseline values calculated should be determined separately for each element in geologically different regions; otherwise, the limit values for contaminated soils may be lower than the natural concentrations (background levels) calculated for an extensive area (Galuszka, 2007). The factors that influence the soil trace element content are very variable. This thus makes the use of normative values of environmental legislation of other countries or regions or global values inappropriate, as they must be determined locally. Currently, published studies that have determined the concentrations and patterns of the spatial distribution of heavy metals in soils for virgin soils appear insufficient or patchy. It was also unclear whether the reported work done in this discipline considered geology as the source of the elements in the soils. Geological sciences reveal that different geological domains present different arrays of rock units and hence local backgrounds and baseline values computed for different geological domains will differ in values. Therefore, to ensure effective environmental management policies based on background and baseline values, local background and baseline values must be determined for the different geological domains. Although a lot of studies have determined the concentration of metals and metalloids in similar areas, there are no categorical studies which determine baseline and background concentrations for a specific geological province in Ghana. This study, therefore, attempts to establish the local background and baseline concentrations of elements within the soils found in the Birimian terrain of the Wass area using probability plots (Q–Q plots) as an important step towards in environmental studies and management in Ghana.

Location, demography and population of study area

The study area forms part of geological field sheet 0503B of Ghana and covers Asankragwa, Akropong, Samreboi and Bogoso, within the Wass area traditional (Figure 1). The area has an estimated population of 282 000 according to the 2000 National population census (Ghana Statistical Service, 2002). The main occupation of the population is farming; primarily the cultivation of food and cash crops like plantain cassava, cocoa, coffee and rubber. Small-scale artisanal gold mining and the illegal artisanal gold mining, popularly known as “Galamsey” are not uncommon in the area. Aside from the large-scale Wassa Mine operated by Golden Star gold at Bogoso, there are medium scale mining activities at Jukwa and Akropong. The area lacks any impactful industries despite the presence of a few exploration companies whose activities are at the various stages of exploratory work. The study area was selected on the basis of the diverse rocks present in the area. It represents a typical example of the Birimian terrain which covers a good portion of the West of Ghana. Soil samples used as part of this study were taken from relatively undisturbed areas within the study area with minimal mining activities and from a deep horizon so as to be representative of the local background and baseline values of the area.

Physiographic and geological settings

The area is predominantly undulating with the highest points averaging about 150 m. Draining the area are the Tano and Ankobra Rivers. The climate is tropical humid with two rainfall patterns. The major rainfall occurs from March to July and the minor season occurs from September to early December and Average annual rainfall is 173 mm. The vegetation in the area has been influenced by the rainfall pattern. The temperature ranges from 29°C to 24°C between March and August, respectively.

The area is underlain by rocks of Birimian System and lies within the southern portion of the Ashanti Greenstone Belt, along the eastern margin within a volcano-sedimentary assemblage located close to the Tarkwaian formation contact. A fault zone to the east separates the Tarkwaian Formation of rock units from the Volcano-sedimentary rocks of the Sefwi group (Parra-Avila et al., 2015). The lithological sequence of the study area is characterized by a sequence of meta-volcanic (basaltic to andesitic protoliths) flows intercalated with metasedimentary rocks.
such as greywacke, magnetite-rich argillite and rare black shale layers, micaschists and felsic porphyry. The area is also intruded by granitoids and some mafic intrusives. Most of the granitoids correspond to typical tonalite-trondhjemite-granodiorite (TTG) suites (Perrouy et al., 2016). Rocks are aggregates of minerals, implying that after weathering different types of elements will be released into the soils and depending on their concentrations may impact on the health of the exposed populations.

**Materials and methods**

A total of 2868 soil samples were collected, dried, and sieved to <106 µm fraction for elemental analysis. The soil samples were conducted on a 1 km$^2$ grid using GARMIN E-TREX 30 GPS device to navigate to the predetermined sampling points. The top 20 cm depth of the soil was collected as a sample from a 30 cm nominal diameter hole. The samples collected were put in labelled Plastic bags. Sample weights of 2 kg were collected at all sample stations. The collected samples were sent to a commercial laboratory for chemical analysis using XRF technique on pressed pellets except for gold that was analysed using Fire Assay. The elements analysed included As, K, Co, Cr, Mn, Ni, Pb, Mg, Fe and Au.

Results obtained from the XRF analysis were interpreted using descriptive statistical analysis. Information such as standard deviation, standard error, and mean for the various elements were calculated. All the variables were transformed using normal score transformation prior to the principal component analysis (PCA), followed by the cluster analysis using a furthest neighbourhood method. The relationships of elements in soil samples were presented in a component matrix and a Dendrogram.

The data normalities for As, Co, Pb, Cr, Pb, Ni, Mg, Fe, K and Mn were examined using one-sample Kolmogorov–Smirnov test (the K–S test of normality) as well as the Shapiro–Wilk tests. The normalised data was then log-transformed to achieve near straight line distribution using Q–Q plot. Outliers that were noticed in the upper and lower extreme corners for the Q–Q plots of the various elements were excluded until the distribution followed a straight line (extreme high and low values, respectively). This was repeated until the best fitness to the straight line was achieved following the methodology by Papastergios, Fernandez-Turiel, Georgakopoulos, and Gimeno (2010) and Karim, Qureshi, and Mumtaz (2015).

The Q–Q plot supported the delimiting three classes that included geochemical background, baseline, and geochemical anomalies on the basis of their geometric
mean (g) and geometric deviations (d) following the computation as demonstrated by Papastergios, Fernandez-Turiel, Filippidis, and Gimeno (2011) and Papastergios et al. (2010) (Table 2). The analytical quality was assessed by inserting quality control and assurance samples SARM 1, SARM 2 and AMIS 17 for accuracy analysis. 

**Results and discussions**

Quality control and assurance analysis performed on the three certified reference materials SARM 1, SARM 2 and AMIS 17 shown in Table 1 displayed no apparent signs of contamination with precision and bias recorded primarily below 9.3%. The recovery rates for the certified reference material (known also as standard sample) varied between 87.5% and 120% (Table 1). This is considered satisfactory for the study relating the calculated recovery rates in a similar study in Rio Doce Basin in Brazil (Guevara et al., 2018).

The summary statistics developed from the 2868 sample results processed to establish the local background and baseline values are presented in Table 2. From Table 2, As averages at 17.36 14 mg/kg with a standard deviation of 15.54. This is not very high suggesting clustered As spread. Meanwhile, the range is between 2 and 246 mg/kg meaning toxic and deficient As concentrations coexist contemporaneously. Toxic concentration of 246 mg/kg will pose a debilitating effect to the exposed population and thus required environmental monitoring to locate and define such terrains. However, comparing the measured average values with local background and baseline values that factor element contributions from the local activities, chemical and surface process may be useful. Co values ranged from a maximum of 43.28 mg/kg to a minimum of 2.64 mg/kg with an average value of 4.84 mg/kg (Table 2). Cr recorded an average value of 761 mg/kg and a minimum value of 12 mg/kg (Table 2). Cr recorded a maximum value of 1500 mg/kg and a minimum value of 12 mg/kg, the mean Cr value measured in this study; suggesting the entire area is deficient in Cr worldwide (i.e., 200 mg/kg).

| Elements | Min | Mean | Median | Standard Deviation | Skewness | Kurtosis | Geometric Mean | Geometric Standard Deviation | Max |
|----------|-----|------|--------|-------------------|----------|----------|----------------|-----------------------------|-----|
| As       | 2   | 17.36| 14     | 15.54             | 5.09     | 48.72    | 43.1           | 1.26                        | 246 |
| Cr       | 12  | 89.52| 81     | 55.03             | 12.68    | 288.12   | 80.74          | 1.54                        | 1500|
| Pb       | 5   | 7.43 | 6      | 4.93              | 10.82    | 250.07   | 6.70           | 1.48                        | 148 |
| Co       | 264 | 4.84 | 3.96   | 2.75              | 3.53     | 33.02    | 6.44           | 1.58                        | 43.28|
| Fe       | 4   | 3.22 | 2.9    | 1.7               | 1.57     | 4.8      | 2.82           | 1.69                        | 0.44 |
| K        | 0.05| 0.77 | 0.76   | 0.35              | 0.56     | 0.86     | 0.68           | 1.72                        | 2.92 |
| Mg       | 0.01| 0.19 | 0.18   | 0.1               | 2.92     | 22.16    | 0.1            | 1.68                        | 1.52 |
| Mn       | 69  | 203.84| 159   | 152.84            | 5.96     | 62.4     | 176.78         | 1.68                        | 2600|
| Ni       | 2   | 10.97| 9      | 8.62              | 4.68     | 57.02    | 1.98           | 8.67                        | 174 |

Table 2. The five classes determined after Papastergios et al. (2011).

| Class                | Concentration |
|----------------------|---------------|
| Negative Anomaly     | <g/gd         |
| Background           | gd-gd         |
| Baseline             | g             |
| Low Anomaly          | gd-gd²        |
| Intermediate Anomaly | gd-gd⁴        |
| High Anomaly         | >gd³          |

Table 1. Summary statistics of major and trace elements in soil samples in the study area (Unit measurements, mg/kg).
the various elemental associations. SiO$_2$ in Cluster 1 is detached from all the other chemicals (Figure 2). This means that soils with more quartz may contain less content of the other minerals implying the SiO$_2$ may be from the hydrothermal quartz veins reported by Kesse (1985), Adjimah et al. (1993) and Griffis et al. (2000) that are associated with the Birimian System of Ghana. Most of these veins host gold mineralization and hence become the target for the artisanal small-scale miners. In their quest to mine the auriferous quartz veins facilitate the spread of the elements released from the underlying rocks through weathering and erosion. Cluster 2 contains Th, Ti, U, and Ba, which occur as oxides, often considered as resistant minerals, unsusceptible to weathering and tend to enrich the secondary environment (Cornu et al., 1999; Scheinost, 2005). The MgO, CaO, Zn, Mn, Cr, Ni, V, Fe, and Al are assigned Cluster 3, which was ascribed to the underlying geology. Lead (Pb) and Cu occurred with the sulphide minerals and these are linked to the auriferous quartz veins deposited as part of the hydrothermal deposit in this area (Kesse, 1985, Adjimah et al., 1993, Griffis et al., 2000). Similarly, the Sr, Na$_2$O, Rb, and K$_2$O assigned in one group (cluster 20) may mainly occur in the mineral lattices. The dissociation of the metalloid As (in a single cluster) from other elements suggests its special feature in the environment. It is possible that As has a weak relation to the underlying rocks, but may be found in hydrothermal veins common in the metasedimentary and volcanoclastic rocks similar to Pb and Cu in this area (Kesse, 1985). The deep weathering resulting in thick regolith profiles at the study area is controlled predominantly by chemical weathering. This weathering type will decompose the rocks and the sulphide minerals (including arsenopyrite) associated with the auriferous quartz veins possibly explaining the adsorption of As by various minerals, such as iron and aluminium oxides, and clay minerals common in tropical soils. The high As averages obtained for BogosoAkropong and Asankragwa confirms As occurrence as an accessory mineral in gold ore deposits particularly hosted in the metasedimentary and volcanoclastic rocks of Ghana (Kesse, 1985). The geochemical variations across the landscape as shown in Table 3 suggest the need to calculate local background and baseline values not just for geochemical anomaly detection but for environmental health management towards the attainment of sustainable development goal on wellbeing and good health for all. The knowledge of the local background and baseline concentrations of elements in specific areas are essential for environmental studies on health (Salminen & Tarvainen, 1997).

**Background and baseline calculations and their usefulness in environmental health monitoring**

Papastergios et al. (2011) method (Table 3) was used to calculate the background and baseline values and other variables useful in assessing element impacts in the environments is presented in Table 3. The background values expressed as a range in this study (Table 5) appear to have values different from continental crustal values calculated by Taylor (1964) and Rudnick et al.

**Figure 2.** Dendrogram using a complete linkage to define element associations in soils.
(2003). The disparities in local background values and the continental crustal values may lead to different predictions and hence a promulgation of unreliable environmental policies. Example the application of using Table 3 in calculating the background value; placed As baseline value at 13.29 in this study compared with the global As values ranging between 10 mg/kg and 15 mg/kg. The calculated As value though falls within worldwide As range but show great contrast between Webb et al. (1979), Zhu, Williams, and Meharg (2008) and Italian reference values for soils for Arsenic. The contrast in background/baseline values from different geographic locations from the established local background/baseline values could lead to several detrimental outcomes to expose people in the affected areas. For instance, if As background is set at 20 mg/kg (Table 6) it will lead to an outbreak of As-related diseases because the people eat what they grow. The authors anticipate the contrast between the calculated local baseline values with the existing globally accepted values to bring some distortions in environmental policies. This thus may influence strategies to remediate health issues linked to excess toxic elements or depleted essential elements. From Table 6 no single calculated baseline value is the same for different geographic locations for the elements. It meant the adaptation of worldwide accepted values or WHO accepted values may be tricky because the controls on element concentrations depend on the underlying geology, local environmental activities, soil-forming processes, geochemical, chemical and physical processes. Similarly, if we compare the baseline values with crustal averages (Table 5) the likely conclusion is As and Cr contaminations with depletions of Pb, Co and Ni in surface soils. It is therefore imperative that using upper continental crustal (UCC) averages as a baseline to monitor environmental health issues may not be accurate for the study area and will result in speculative conclusions that may be detrimental to human health particularly for the toxic elements.

The safest approach is to use the calculated baseline values in the study because it incorporates element concentrations in both precinct and contaminated soils. The calculated baseline values for As and Cr in the study shown in Table 6 appear to be in a similar As in column 2 and Cr in column 4. All others are different because of the different environmental activities and variations in the underlying geology forming the soils. From Table 4 and using Sinclair’s Experiential model (1991), the background limits for As, Cr, Pb, Co and Ni in soils for the study area were 6.41 mg/kg, 52.55 mg/kg, 9.89 mg/kg, 10.21 mg/kg and 17.18 mg/kg, respectively, for the Birimian of Southwest Ghana. The choice of these background values incorporated the global accepted values for these elements and the consequences thereof when toxic elements particularly exceeded these accepted global values.

A background value ranging between 4.1 and 10.2 mg/kg and a baseline value of 6.4 mg/kg was determined for Co. This indicates that 1437 samples (50.1% of the 2868 samples) belong to the background class. These values are below the normal Co range of 100 mg/kg for mafic rocks and 1 mg/kg –15 mg/kg for acidic rocks (Kabata-Pendias, 2010). Weathering mechanisms that transform and distribute Co in soils are very complex due to their differing oxidation states and also the prevalent microbial activities (Ma & Hooda, 2010). The baseline value for Co is 8.0 mg/kg. This, however, is higher than the measured baseline value of 6.44 mg/kg in the study. Cobalt acts as a bio-essential trace element for bacteria, plants, and humans in the natural environment. The low baseline value calculated implies inadequate Co supplies to...
plants and humans. This thus makes environmental monitoring of Co still important because Co concentration levels can reach hazardous levels in humans as its bioaccumulation may damage vital organs such as the liver, kidney, pancreas, and heart (Czarnek, Terpiłowska, & Siwicki, 2015; Lange et al., 2017). Magnesium recorded a background value ranging between 0.062 wt. % – 0.173 wt. % with a baseline of 0.103 wt. %. From Mg data set, 2094 samples (i.e., 73% of the 2868 samples collected) have values in the background class. The source of Mg measured in the samples out of the total collected samples to be within the background class. Since it is an essential mineral micronutrient that acts as an intracellular ion for all types of cells; the low concentrations in soils may impact on the population if their source of dietary supplement is via food. It also plays a role in the maintenance of fluid and electrolyte balance. A dietary survey in the US indicated the average dietary K intake is about 2,300 mg/day for adult women and 3,100 mg/day for adult men. Diseases related to K-deficiency may not affect the population and there will not be the need for K-supplemented pills to make up for K-deficiency in the US. But the same might not be said about the study area where most areas have K-concentrations in the background class. Correspondingly, Cr had a background value between 52.5 mg/kg– 124.1 mg/kg with a baseline value of 80.7 mg/kg. From the chromium data 2037 samples (71% of the 2868 samples) belong to the background class. Cr contents similar to these values are associated with acidic and argillaceous rocks (Kabata-Pendias, 2010). Most soil Cr exists as Cr$^{3+}$ and is marginally mobile in very limited acidic media. Cr$^{6+}$ has been reported to be toxic for plants and animals whereas Cr$^{3+}$ in certain doses has a detrimental effect for the biochemical activity of soils (Shrivastava, Upadhy, Seth, & Chaturvedi, 2002). There are Cr-related diseases which can be evaluated for geographic area relative to the calculated baseline value of Cr.

### Table 5. Comparison of estimated background values (milligrams per kg of dry weight) with the continental crustal averages.

| Element | This Study | Continental crustal average |
|---------|------------|----------------------------|
| As      | 6.41–27.56 | 1.8                       |
| Cr      | 52.55–124.06 | 100                      |
| Pb      | 4.54–9.89   | 12.5                      |
| Co      | 4.07–10.21  | 25                        |
| Ni      | 4.38–17.18  | 75                        |

### Table 6. Comparison of estimated baseline values (milligrams per kg of dry weight) with the values published in the literature.

| Element | 1     | 2     | 3     | 4     | 5     |
|---------|-------|-------|-------|-------|-------|
| As      | 13.29 | 14    | 9.92  | 9.4   | 20    |
| Cr      | 80.74 | 36    | 100.56| 79.3  | 150   |
| Pb      | 6.69  | -     | 33.05 | 19.5  | 100   |
| Co      | 6.44  | -     | 22.62 | 9     | 20    |
| Ni      | 8.67  | -     | 31.97 | 19.45 | 120   |

1 = This study  
2 = Jiangxi Geochemical Survey (1987)  
3 = Webb et al. 1978  
4 = Soil background in Taihu, China (Zhu et al., 2008)  
5 = Italian reference values for soils, D. LGS 152/2006
Ni calculated background value in the study ranged from 4.4 mg/kg, 17.2 mg/kg and a calculated baseline value of 8.7 mg/kg. A total of 1992 samples (i.e., representing 69.5% of the 2868 samples collected) belong to the Ni background class. As seen in the study, the distribution of Ni is similar to Fe and Co. Ni occurrence in the area may be associated with the underlying sulphide-associated rocks (Figure 2).

Another known toxic element Pb reported a background value ranging from 4.5 to 9.9 mg/kg and a baseline of 6.7 mg/kg. The data set shows that 82.7% of the samples fit the background class of Pb. The low Pb values obtained in the study could be the primary Pb in the underlying rocks hence source is geogenic. Whilst the high Pb assays recorded in the area may be associated with the chalcophile element corridors in the underlying rocks or from human-induced activities. Some contributions might come from the Light Industries where vehicle fumes, oil spillages and vehicle batteries can introduce Pb into the environment. Elsewhere, Pb concentration levels exceeding 100 mg/kg was linked to industrial pollution in countries such as Japan and Great Britain (Bellis, Satake, Noda, Nishimura, & McLeod, 2002; Markus & McBratney, 2001).

A comparison of the baseline values calculated in this study with the average crustal values and similar works conducted shows that the baseline value of Co is relatively low (Table 5 and Table 6). The baseline value of Cr is comparable with values calculated for Taihu in China and slightly lower than the average crustal value for Cr. The calculated baseline for Ni in this study is relatively low compared with the average crustal value and other values calculated for Ni as shown in Table 4. As baseline 131.2 mg/kg falls in the range estimated by global accepted value in soils (10 mg/kg – 15 mg/kg) but outside the Italian reference value for As in soils (20 mg/kg). Food and most drinking water are exported so this baseline for As may not lead to any environmental health problems. Adapting this value will result in As-related diseases such as heart diseases (hypertension-related cardiovascular diseases) cancer, stroke (cerebrovascular diseases), chronic lower respiratory diseases, and diabetes Järup (2003), Tchounwou, Yedjou, Patlolla, & McLeod, (2012). The baseline value calculated for Pb (6.70 mg/kg) in this study was lower than the average crustal value of 12.5 mg/kg and much lower than the Italian reference value for Pb in soils peg at 100 mg/kg.

**Conclusion**

Background and baseline values have been calculated for As, Cr, Pb, Co and Ni. The background values were 6.41 mg/kg for As, 52.55 mg/kg for Cr, 9.89 mg/kg for Pb, 10.21 mg/kg for Co and 17.18 mg/kg for Ni. The calculated baseline values for As, Cr, Pb, Co and Ni were 13.2 mg/kg, 80.7 mg/kg, 6.7 mg/kg, 6.4 mg/kg and 8.7 mg/kg, respectively. The inconsistencies in calculated background and baseline values relative to the worldwide values further underscore the need to conduct environmentally health-related studies. The authors conclude that local background and baseline value application to establish hotspots and cold-spots of disease-causing elements as a vital step in environmental health management.

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**Disclosure statement**

No potential conflict of interest was reported by the authors.

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