# APPLIED GEOCHEMISTRY: RECENT TRENDS AND ISSUES IN AFRICA (2017 - 2020)

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## SUMMARY

This Report looks at the rate of application of Applied Geochemistry (AG) in Africa during the period 2017 to 2020. It is a follow-on from the AG Africa Report for the period 2012 - 2016 (See Davies, 2016). The assessment is based on the AG output presented in terms of volume of field- and laboratory work, other research activities and publications.

In the past few years, there has been increasing realisation of the role of geochemical variables as causality cofactors of diseases of unknown aetiology (DUA) as well as occasional disease outbreaks in various geographical regions of Africa. This relationship has triggered a flurry of research initiatives on the Continent in understanding the geochemical fluxes of both nutritional and potentially toxic elements (PTEs) in the groundwater-soil-food crop continuum, that largely define the nutritional quality of the African diet, and hence the correct balance of micronutrients and vitamins in metabolic processes.

## WATER, SOIL AND AIR POLLUTION

By far the largest volume of AG research in Africa over the last 3 - 4 years (2017 - 2020) has centred around an understanding of the geochemical circulation of nutritional and potentially toxic elements (PTEs) in the water, soil and air environments (Table 1). This is consistent with the growing realisation of the important role of nutritional elements in shaping the diet, the criticality of their ‘‘optimal range’’ of intake in metabolic processes and hence, in warding off disease (e.g., Failla, 2003). In the same way, knowledge of the fluxes of PTEs in the water, soil and air environments is essential for their (PTE) exclusion from the food chain.

Projects involving pollution of the water, soil and air environments have been conducted with respect to the source of pollution - from agricultural activities, industrial activities, mining, leachates from dumpsites, and so on. These studies have been widely supported in recent years, thanks to a favourable shift in international funding policies. For example, results from the completed UNESCO/SIDA funded IGCP 594 and 606 projects on: ‘Environmental Health Impacts of Mining (on the water, soil and air environments) in Africa’ have been compiled in two Special Issues of the Journal of Geochemical Exploration: (Kribek et al., 2014, JGE, Vol. 144, Part C; and Toteu et al., 2019, JGE Vol. 204/205), both of which have, since publication, been experiencing an extraordinary download rate.

### Water Pollution

Groundwater obtained from wells and boreholes constitutes the main source of drinking water for many African communities; but this water is often of low quality since many of these wells are located close to sanitary facilities (Fayiga et al., 2018). Thus, much of the recent research on water chemistry and pollution in Africa has centered around the detection of unacceptably high values of PTEs in water bodies; in particular, those from which drinking water in tapped. The objective of such studies has been to decipher the health implications and proffer mitigative measures (e.g., Gilbert et al., 2017; Enitan et al., 2018; Adewoyin et al., 2019; Nwankwo et al., 2020; Ricolfi et al., 2020).

Table 1. Ranking Africa's recent (2017 - 2020) Applied Geochemistry Output (Based on Internet Searches of 07.09.2020)

| Rank | Area of Activity (Field campaigns; Research; Publications; etc.) | Output (%) | Remarks |
|---|---|---|---|
| 1 | Water Quality | 49.0 | Proliferation of research on water quality has been as a result of the need to understand health risks posed by unacceptably high levels of toxic elements in potable water supplies, as well as the realisation by all stakeholders that climate change would exacerbate the already dire water quality situation that currently exists |
| 2 | Air Quality | 33.3 | The upsurge in research effort on air quality is in line with global activities in the area of atmospheric chemistry, to address climate change and health issues. In Sub-Saharan Africa where most of the Continent's mining activities are concentrated, the air quality situation is most serious, especially with regard to radon entry into homes, and its accumulation in underground mines |
| 3 | Soil Quality (Contaminated Land) | 10.2 | The main sectors responsible for soil pollution in Africa are mining, agriculture and waste disposal. A huge research effort supported by international funding has been mounted to address this, through measures such as phytoremediation. Much effort is being expended in understanding the processes and mechanisms of uptake of nutritional and PTEs from the soil through food crops, and their roles in mediating metabolic processes and influencing immune system functions |
| 4 | Climate Change Chemistry | 4.1 | A flurry of activities is taking place, in line with the trend of research on atmospheric chemistry and global change phenomena |
| 5 | Medical Geology (Environmental Geochemistry and Health) | 1.5 | As the link between geochemical cofactors and certain environmental diseases becomes clearer and more firmly established, we will continue to see a rise in research activities in this field |
| 6 | Isotope Geochemistry; inorganic and biogeochemical processes | 0.4 | A significant rise in the use of chemostratigraphy and isotopic dating is realised, as researchers begin to appreciate the potential of both stable and radiogenic isotopes to provide answers beyond the reach of geology |
| 7 | Geochemistry Aspects of Waste Disposal [Including Mine Wastewaters (AMD)] | 0.3 | The geochemical aspects of hazardous and non-hazardous waste disposal in Africa remains poorly researched. This is apart from the subject of acid mine drainage (AMD), which continues to be of immense environmental concern, particularly in South Africa - one of few African countries with established institutional structures for articulating waste disposal policies |
| 8 | Marine Geochemistry | 0.3 | The volume of research on marine geochemistry in Africa is very low. Surprisingly, little geochemistry is applied in exploration for offshore resources, despite the many petroleum discoveries made in the last few years |
| 9 | Geochemistry in Agriculture | 0.3 | Research into chemical technology that would help African farmers improve yields continues to gain impetus as the urgent need to meet food security targets grows |
| 10 | Geochemistry in Mineral/(Ore) Exploration (GMOE) | 0.3 | Numerous geochemical prospecting programmes were mounted or continued, largely by mining companies. However, many geochemical and mineral target maps that are generated are not put in the public domain, for reasons of confidentiality, which partly explains the unexpected low ranking of GMOE. |
| 11 | Urban Geochemistry | 0.2 | Some data are available for the separate compartments of the water soil and air environments; but this area of AG research in Africa is still very much in its infancy |
| 12 | Extraterrestrial Geochemistry | 0.1 | The volume of research on Extraterrestrial Geochemistry is low compared to work done in other continents; but awareness of its importance is growing [See below, Sections 2 and 3 of: The European Association of Geochemistry-The Geochemical Society (EAG-GS) Outreach Programme to Africa on 'Africa Initiative for Planetary and Space Sciences'] |
| | | **100.0** | |

## Soil Pollution

Identified sources of soil pollution in Africa include agricultural activities, mining, roadside emissions, auto-mechanic workshop effluents, leachates from refuse dumps and e-waste (Fayiga et al., 2018). Oil spills are a major problem in large oil-producing African countries such as Nigeria and Angola.

Soil micronutrient (boron, iron, copper, manganese, molybdenum, selenium, zinc, chlorine, cobalt, etc.) deficiencies are a major problem for crops, livestock and people, and is a subject keenly researched at present (See e.g., Hengl et al., 2020). So also are the consequences of an excess of PTEs in the soil. The last few years have therefore seen a rise in research effort in understanding PTE fluxes in the soils, with the objective of assessing the health implications of unacceptably high levels of these elements (See e.g., Dalton et al., 2018; Nde and Mathuthu, 2018; Kapwata et al., 2020; Kihara et al., 2020; Okereafor et al., 2020). The British Geological Survey (BGS) Project (2015 - 2020): "Strengthening African capacity in soil geochemistry to inform agriculture and health policies" (BGS, Updated 2020) clearly embodies these objectives.

**Air Pollution**

"Because air pollution is not monitored in Africa to the same extent as other parts of the world, we are not only potentially underestimating the impact - we might also not know how bad it is until it is too late." - UNICEF, 2019.

Air pollution in African cities stems largely from sources that include particulates and smoke from fossil fuel combustion, vehicular emissions, roadside dust containing pathogens and indoor radon concentrations in ambient air.

Despite the increasing awareness that has produced a surge in air quality research, there is still a dearth of air quality data in Africa. According to a new UNICEF (2019) Report, " … only about 6% of children [in Africa] live near reliable, ground-level monitoring stations that provide real-time data on the quality of air they are breathing - and it is likely that we are only scratching the surface in terms of understanding its full impact on children's health. This is compared to about 72% of children who live near reliable monitoring stations across Europe and North America. Increasing the base of reliable, local, ground-level measurements would greatly aid effective responses to this poorly-understood killer of children across the continent."

Exposure to airborne radon progeny in the domestic environment, but also in underground mine settings, yields the largest source of exposure to ionising radiation of the population.

Radon research in Africa

There is a dearth of studies on radon concentrations and its fate in the African geosphere. This situation is well reflected in the data-deficient radon map (Zielinsky, 2014; Fig.1) presented during a World Health Organisation project of 2017.

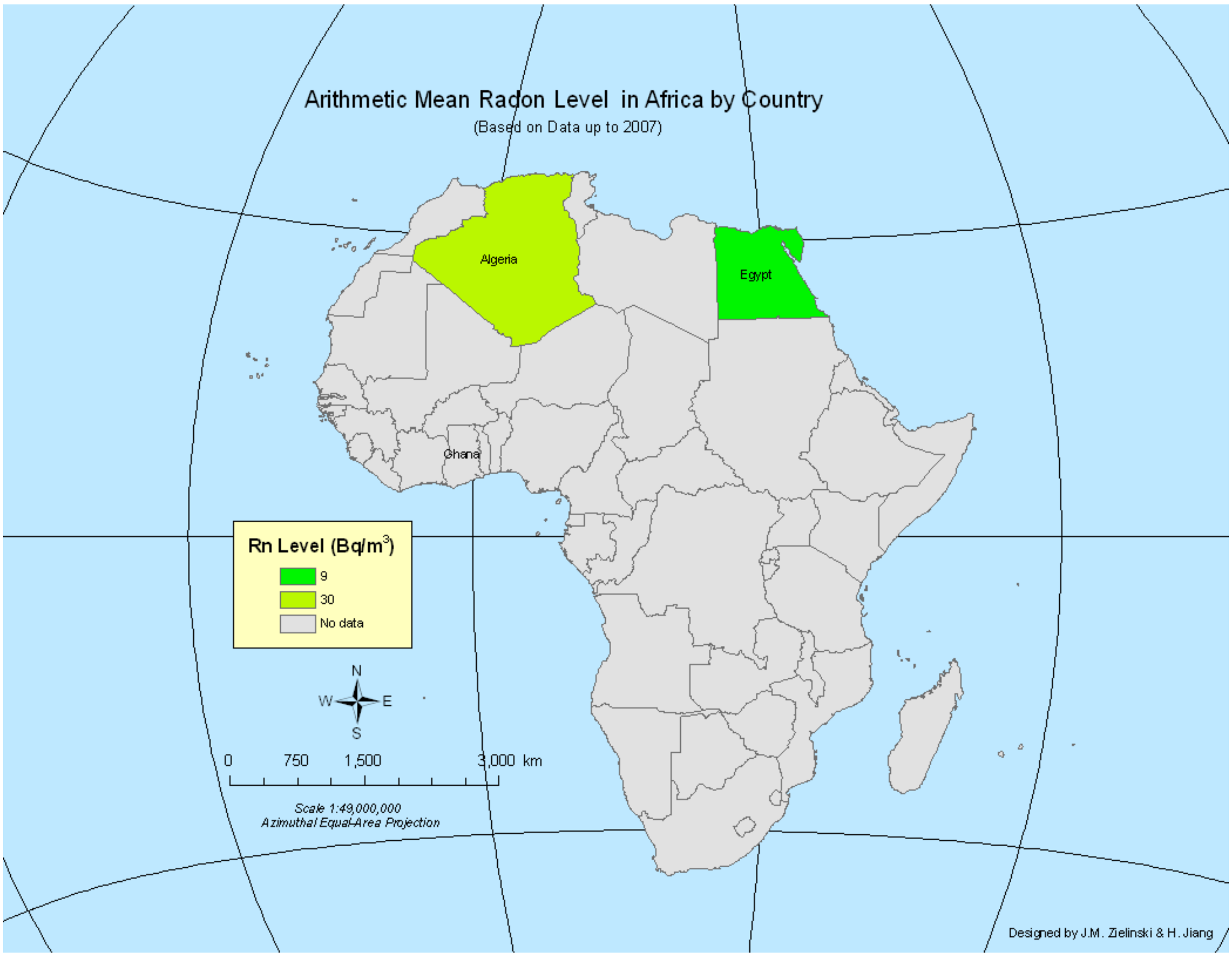


Fig. 1. Africa: Arithmetic mean of radon, by country. Credit: Zielinsky and Jiang. Source Zielinsky, 2014.

Greater awareness of the severity of the health consequences of radon exposure in homes and underground mines of Africa has brought about a rise in the number of studies on 'Radon in Africa' in the last 4 years (e.g., Botha et al., 2017; Kamunda et al., 2017; Masevhe et al., 2017); Botha et al., 2018; Bezuidenhout, 2019; Herbst/CANSA, 2019; Le Roux et al., 2019 and Moshupya et al., 2019). Most of these studies address radon exposure situations and health effects in South Africa. So, a lot more needs to be done to tackle radon exposure problems in other African countries, especially in homes located in the neighbourhood of uranium and gold mining centres.

**GEOCHEMICAL VARIABLES AS PLAUSIBLE CAUSALITY CO-FACTORS IN SUDDEN DISEASE OUTBREAKS AND OTHER 'DISEASES OF UNKNOWN AETIOLOGY' (DUA)**

Sudden physical and/or chemical changes in soil, water or air composition as a result of some geological/geochemical/biochemical phenomena or some other geoenvironmental attributes such as latitude, altitude or seasonal variations at specific localities, ought to be considered more deeply by teams investigating the causes of enigmatic disease outbreaks whose aetiology cannot be immediately identified. Other categories of DUAs should also be considered in a similar vein.

*Nodding disease*, observed in Southern Sudan and Norma in many parts of Sub-Saharan Africa are examples of diseases for which the aetiological agents, till now, remain elusive. Some examples of DUA whose aetiology may well be linked with a geochemical cofactor are given in Table 2.

Table 2. Probable geoenvironmental co-factor(s) in diseases of unknown aetiology

| | | | Probable geoenvironmental co-factor(s) | | | |
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| **DUA** | **Presentation** | **Geographical Distribution/Incidence** | **Geochemical (including trace element mediated immune response)** | **Geographical patterns/Climatic or Seasonal variations** | **Internal or External Earth processes** | **Remarks** |
| Acrocyanosis | *Acrocyanosis* is a peripheral vascular disorder which presents as a persistent bluish or cyanotic discolouration of the extremities, most commonly occurring in the hands | Geographical locale (latitude; urban versus rural setting) uncertain - Kurklinsky et al., 2011 | Chronic arsenic toxicity - Tseng, 1977; Mak, 1988 | Cold climate - Crocq, 1896; Carpentier, 1998; Cold environments - Das and Maiti, 2013; Kent and Carr, 2020 | - | "Diagnosis remains mostly clinical, and pathological mechanisms vary, suggesting that acrocyanosis may not be a single entity" - Kurklinsky et al., 2011 |
| Acute Febrile Illness | *Acute febrile illness* (AFI) is characterised by malaise, myalgia (pain in muscle or group of muscles) and a raised temperature that is a nonspecific manifestation of infectious diseases in the tropics (Bashkaran et al., 2019) | Sub-Saharan Africa; Tropics and Sub-Tropics | Viral respiratory tract infections - Crump et al., 2013; D'Acremont et al., 2014; Iron, zinc, magnesium and calcium **not** significantly related to fabrile convulsion - Amouian et al., 2013 | Clear seasonal trend - Kaboré et al., 2020 | - | - |
| Acute Severe Asthma | *Asthma* is characterised by chronic airway inflammation, resulting in periodic wheeze, cough and breathlessness (See Carlsson and Bayes, 2020). | Worldwide | Respiratory tract infections - Johnston et al., 1995; Jackson and Johnston, 2010; Air pollution - Guarnieri and Balmes; 2014; Shmool et al., 2014 | Cold weather - Hyrkäs et al., 2016; Weather changes - D'Amato et al., 2018 | - | The mechanisms by which these environmental stimuli and viruses initiate asthma or cause worsening of the disease are still unknown - Kostakou et al., 2019 |
| Alzheimer's Disease (AD) | *Alzheimer's disease* (AD) is the most common neurodegenerative disorder and the leading cause of dementia (i.e., the particular group of symptoms shown). It becomes worse with time (degenerative). The symptoms expressed are as a result of the damage or destruction of nerve cells (neurons) in parts of the brain involved in thinking, learning and memory (cognitive function) | By 2009, the global prevalence of dementia was estimated at 3.9 % in people aged 60+ years, with the regional prevalence being 1.6 % in Africa, 4.0 % in China and Western Pacific regions, 4.6 % in Latin America, 5.4 % in Western Europe, and 6.4 % in North America (Qui et al., 2009). | Significantly different (p less than 0.05) mean concentrations of bromine, chlorine, cesium, mercury, nitrogen, sodium, phosphorus, and rubidium were observed in AD bulk brain samples compared to controls - Ehmann et al., 1986; Varying trace element relationships with AD severity, with aluminium deposits greater in severely affected AD brain - Jagannatha Rao et al., 1999; Loef and Walach, 2012; Bagheri et al., 2018; Liu et al., 2019; Anomalous concentration levels of metals in metal-binding proteins have growth inhibition functions on neurons - Constantinidis, 1991; Richarz, and Brätter, 2002; Trace metals and abnormal | Long-term exposure to $O_3$ and $PM_{2.5}$ above the current US EPA standards are associated with increased the risk of AD - Jung et al., 2015;. Association between Alzheimer Dementia mortality rate and altitude - Thielke et al., 2015; Hu et al., 2016; Lall et al., 2019; Koester-Hegmann et al., 2019; Associations with seasonal temperature - Wie et al., 2019; Global warming and neurodegenerative disorders - Habibi et al., 2019 | - | In 2019 Alzheimer's Disease International (ADI) estimates that there are over 50 million people living with dementia globally, a figure set to increase to 152 million by 2050 (ADI, 2019). In both developed and developing nations, Alzheimer's disease has had tremendous impact on the affected individuals, caregivers, and society. Because developing countries are projected to see the largest increase in absolute numbers of older persons, their share of the worldwide aging population will increase from 59 % to 71 % (Qui et al, 2009). "Because occurrence of AD is strongly associated with increasing age, it is anticipated that this dementing disorder will pose huge challenges to public health and elderly care systems in all countries across the world" (Qui et al, 2009). |

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| | | | metal metabolism influence protein aggregation, synaptic signalling pathways, mitochondrial function, oxidative stress levels, and inflammation, ultimately resulting in synapse dysfunction and neuronal loss in the AD brain - De Benedictis et al., 2019 | | | |
| Chronic Kidney Disease of unknown aetiology (CKDu) | The predominant feature of *CKD* is tubular atrophy and interstitial fibrosis (thickening and scarring of the tiny air sacs and interstitial tissues in the lungs) | Reported in many parts of the world, especially among rural farming communities. High incidence in low- and middle-income countries over last two decades - Mills et al., 2015; Bikbov et al., 2020; "In 2017, the global prevalence of Chronic Kidney Disease (CKD) was 9·1% (95% uncertainty interval [UI] 8·5 to 9·8), which is roughly 700 million cases" - Cockwell and Fisher, 2020 | Synergistic reaction between cadmium and diabetic-related hyperglycaemia - Edwards and Prozialeck, 2009; Consumption of (polluted) well water suggested; need for investigating role of cadmium - Wanigasuriya et al., 2011; "Geographical mapping showed that villages with a high prevalence of CKDu are often related to irrigation water sources and/or located below the level of the water table" (Jayasekar a et al., 2013); Toxins/heavy metals - Jha et al., 2013; Groundwater geochemistry (high levels of fluoride, cadmium, arsenic) - Wijetunge et al., 2015; High ionicity of drinking water due to fertilizer runoff - Dharma-Wardana et al., 2015; Rajapakse et al., 2016; Heavy metal exposure; water pollution - Lunyera et al., 2016; Synergistic reaction between fluoride and water hardness - Sengupta, 2013; Wickramarathna et al., 2017; Balasooriya et al., 2019 | Altitude - Almaguer et al., 2013; Heat stress nephropathy due to global warming - Glaser et al., 2016 | - | "There have been several global epidemics of CKDu. Some, such as Itai-Itai disease in Japan and Balkan endemic nephropathy, have been explained, whereas the aetiology of others remains unclear" - Gifford et al., 2017. "Those affected do not have common risk factors or underlying conditions that lead to CKD, such as diabetes, immune-mediated glomerulonephritis, or structural renal disease" - Caplin et al., 2019 |
| Geographic Tongue | *Geographic tongue* (also known as *benign migratory glossitis*) is an inflammatory disorder that usually appears in a map-like (geographic) pattern on the dorsum and margins of the tongue. Typically, affected tongues have | A common condition, affecting 2-3% of the adult general population, worldwide (Ship et al. 2003). | Iron and zinc deficiency; Vitamin B12 - Ogueta et al., 2019; Nandini et al., 2016; Picciani et al., 2016 2017 | - | - | Some studies (e.g., Khayamzadeh et al., 2019) showed that patients with geographic tongue have lower levels of salivary zinc, compared to control groups |

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| | a bald, red area of varying sizes that is surrounded, at least in part, by an irregular white border | | | | | |
| Kawasaki Disease (KD) | *Kawasaki syndrome* is an acute, self-limited vasculitis (inflamed blood vessels) of infants and children with unknown aetiology.<br><br>Signs of KD include prolonged fever associated with rash, red eyes, mouth, lips and tongue, and swollen hands and feet with peeling skin. The disease causes damage to the coronary arteries in a quarter of untreated children and may lead to serious heart problems in early adulthood | KD occurs worldwide; most prominently in Japan, Korea, and Taiwan, reflecting increased genetic susceptibility among Asian populations (Rowley and Shulman, 2018).<br><br>The epidemiology of KD in Africa is very ill-defined, which inevitably leads to misdiagnosis and the reporting of very few cases. This gives the impression that the condition is rare in Africa - Badoe et al., 2011; Animasahun, 2017; Noorani and Lakhani, 2018. The presentation of KD is similar to that of measles (which is very prevalent in Africa), so the exact prevalence (of KD in Africa) is difficult to ascertain - See e.g., Badoe et al., 2011; Davaalkham et al., 2011 | Environmental exposure to mercury - Orlowski and Mercer, 1980; Mutter and Yeter, 2008; Yeter et al., 2016; Portman et al., 2018; Airborne pathogens or toxins - Rodo et al., 2014; 2016 | Decades of research have been unable to pinpoint the cause of the disease, but its distinct seasonality can hardly be in doubt - UCSDH, 2013; Lin and Wu, 2017; Rypdal et al., 2018; Kim, 2019; Elakabawi et al., 2020.; | - | (i) " … Thus, these twin studies suggest that environmental factors contribute more to the development of KD than genetic factors among individuals with the same ethnicity." Hara et al., 2016.<br>(ii) The temporal association between the COVID-19 pandemic and the results of RT-PCR and antibody testing suggest a causal link between Kawasaki disease and COVID-19 - Toubiana et al., 2020 |
| Multiple Sclerosis (MS) | *Multiple Sclerosis* is a demyelinating disease (a nervous system disease in which the insulating covers of nerve cells in the brain and spinal cord are damaged). This damage disrupts the ability of parts of the nervous system to transmit signals, resulting in a range of signs and symptoms , including physical, mental, and sometimes psychiatric problems (Compston and Coles, 2002, 2008; Murray et al., 2012). Kister et al. (2013) list 11 specific symptom domains commonly affected in multiple sclerosis: mobility, hand function, vision, fatigue, cognition, bowel/bladder function, sensory, spasticity, pain, depression, and tremor/coordination | Distribution is worldwide. There is a striking *latitudinal* gradi-ent in *multiple sclerosis* (MS) prevalence (Simpson Jnr. et al., 2011) | Metabolic imbalance of trace elements/metals - Rieder et al., 1983; Smith et al., 1989; Melø et al., 2003; Tamburo et al., 2015; Bredholt and Frederikson, 2016; Janghorbani et al., 2017; Sarmadi et al., 2020 | People who live in higher geographical latitu -des may receive lower levels of sunlight, and therefore have lower vitamin D levels which could explain why there is a higher incidence of MS in countries with higher latitudes - MS International Federation, 2016) | - | - |
| Nodding disease | *Nodding disease* is characterised by an occasional nodding of the head, as in | This is an emerging disease in South Sudan, southern Tanzania, and northern Uganda. The | Deficiency of vitamin B6 (pyridoxine) and other micronutrients | Climate change - Donnelly, 2012. cold weather - Kaiser et al., | Living in the vicinity of fast-flowing streams, the | - |

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| | epilepsy, with seizures, stunted growth, and mental retardation sometimes occurring | exact prevalence and geographic distribution of the disease in the affected countries is unknown - Korevaar and Visser, 2013 | such as vitamin A, selenium, and zinc - GU/WHO, 2012 | 2000; Nyugura et al., 2011 | breeding habitat of the black fly -Donnelly, 2012 | |
| Noma | *Noma* (*cancrum oris* or *gangrenous stomatitis*), is a severe and progressive gangrenous infection (body tissues die as a result of infection or inadequate blood supply) that affects the mouth and face | Mainly observed in tropical countries, particularly Sub-Saharan Africa. True global incidence unknown; but estimated incidence of 30,000 - 40,000 has been suggested by Srour et al. (2017) | Deficiencies of trace elements and amino acids influencing the efficacy of the immune system: iron, zinc, cysteine, methionine, serine, and glycine - Baratti-Mayer et al., 2003; Malnutrition - Srour et al., 2017; Srour and Baratti-Meyer, 2020 | - | - | Patients generally live in extremely poor conditions, frequently located in remote rural areas |
| Parkinson's disease (PD) | *Parkinson's disease* (PD) is a progressive heterogeneous, multisystem and neurodegenerative nervous system disorder that affects movement. The cardinal features of Parkinson's disease are (i) tremor, mainly at rest; (ii) muscular rigidity, which leads to difficulties in walking, writing, speaking and masking of facial expression; (iii) *bradykinesia*, a slowness in initiating and executing movements; and (iv) stooped posture and instability (Sian et al., 1999).<br><br>Parkinson's disease occurs when nerve cells, or dopamine-rich neurons in an area of the brain that controls movement called the *substantia nigra*. become impaired and/or die. But the complete series of steps leading to this cell death is still vague, and the underlying causes remain one of medicine's greatest mysteries | Worldwide occurrence. According to the 2016 Dorsey and GBD Collaborators Study published in 2018, 6·1 million (95% uncertainty interval [UI] 5·0 -7·3) individuals had Parkinson's disease globally, compared with 2·5 million (2·0-3·0) in 1990 | Association with metal and trace element concentration in urine, serum, whole blood and cerebrospinal fluid - Bocca et al., 2004; Forte et al., 2004; Gellein et al., 2008; Zhao et al., 2013; Combination of molybdenum deficiency and purine ingestion - Bourke, 2018; Significant association between the PD mortality rates and soil concentrations of selenium, strontium, and magnesium - Sun, 2018; Adani et al., 2020; Lemelle et al., 2020 | Existence of seasonality (related to temperature) in Parkinson's disease symptoms - Rowell et al., 2017; Improvement of PD symptoms at high altitude - Capcha et al., 2018; Thomas, 2019 | - | Regional maps depicting correlations between the distribution of PD and soil geochemistry which would be very helpful in this aetiological debate, are very rare in the published literature (See an example in: Sun, 2018 for PD distribution in the United States) |

## THE AFRICA GEOCHEMICAL DATABASE

During 2017 - 2020, large-scale geochemical activities involving sampling, analyses and data handling techniques related to the "Africa Geochemical Database (AGD) Project", were at a low ebb. Only a few geological surveys (e.g., Geological Survey of Namibia; Council of Geoscience of South Africa) recorded further work on regional geochemical database programmes that were already started. Reasons for the lowly position of the AGD in geoscience agendas of African countries are well articulated in the 2018 Annual Report of the International Union of Geological Sciences Task Group on Global Geochemical Baselines (IUGS-CGGB, 2019). A number of international workshops with significant African participation were held during the period under review, at which various technical aspects of the Global Geochemical Database Project, useful to the AGD campaign, were discussed.

In 2017, the GEO Group on Earth Observations tabled for a second time, the Project Proposal (Activity ID77): "Africa Geochemical Baselines", for support by EuroGeoSurveys, IUGS/IAGC and others. The Project's aim was: **"To develop a land base multi-element geochemical baseline database for mineral resource and environmental management"**. The Proposal also described a work programme for the period 2017 - 2019. The Project is within the vision of GEO: "To realise a future wherein decisions and actions, for the benefit of humankind, are informed by coordinated, comprehensive and sustained Earth observations and information" and "To develop a geochemical baseline database for the entire African continent through systematic sampling and chemical analysis according to the specifications of IGCP 259 'International Geochemical Mapping' (Darnley et al., 1995). We propose using only one sample medium, depending on terrain type, namely overbank or floodplain or catchment basin sediment, which is generally alluvial (or agricultural soil)."

Analytical Geochemistry

Among the reasons given for the low scientific output in the AGD Programme (geochemical sampling, laboratory analyses, data processing and data portrayal) is the problem of inadequate capacity in analytical instrumentation across Africa; so also is the lack of technical expertise for its operation. Problems associated with the poor analytical geochemistry performance of African laboratories are highlighted in the 2018 Annual Report of the IUGS Task Group on Global Geochemical Baselines (IUGS-CGGB, 2019).

**The European Association of Geochemistry-The Geochemical Society (EAG-GS): Outreach Programme to Africa**

Under the auspices of the EAG-GS, the following events were held during the period under review:

1. EAG-GS 2017 - Short course: Early Earth Life and Mineral Systems.

Presenter: Assoc. Prof. Axel Hofmann, University of Johannesburg, South Africa.

The short course explored the relationship between surface processes, evolution and habitat of life, and the formation of mineral deposits on the early Earth. It investigated the geochemical, mineralogical, environmental and biological evolution of the Earth's surface and immediate subsurface from its volcano-sedimentary record 4.0 to 2.0 billion-years-old.

2. EAG-GS 2018 - Africa Initiative for Planetary and Space Sciences produced two International Workshops held in February, 2019 (First Africa Initiative for Planetary and Space Science Workshop, Addis Ababa, Ethiopia) and May, 2019 (Eastern Africa Global Navigation Satellite Systems and Space Weather Capacity Building, Pwani University, Kenya), respectively.

The Workshops' objectives were:

- To connect African Planetary and Space Scientists with their international peers;
- To build a road map for Planetary and Space Sciences in Africa, by identifying key research areas where African scientists can make significant contributions;
- To solicit sponsors to support the development of this research domain in Africa;
- To contribute to sustainable development in Africa through research, education, and public outreach in Planetary and Space sciences.

3. The 2019-2020 EAG-GS Outreach Programme to Africa took the form of a series of workshops and seminars on meteoritics and planetary sciences in universities and institutes across Africa during 2019 - 2020.

2019-2020 Outreach Lecturer: Hasnaa Chennaoui Aoudjehane (Hassan II University of Casablanca)

Dates, titles and venues

(i) 28 January 2019: Seminar Title: 'Morocco and Mauritania meteorites: A large contribution to meteoritics and planetary sciences'
Venue: University of Nouakchott and l'Institut Français de Mauritania, Nouakchott, Mauritania

(ii) 17 March 2019: Workshop Title: Meteorites of Morocco and the Arab world
Venue: National Research Center, Cairo, Egypt

(iii) 29-30 November 2019: (a) Seminar Title: Meteorites in Morocco and Arab countries
(b) Workshop on identification of meteorites
Venue: Cité des Sciences de Tunis and Faculty of Science of Tunis, Tunisia.

## CONCLUSION

The trend in AG research in Africa during the last few years has been towards determining the circulation of both nutritional elements and PTEs in the water-soil-food crop nexus, that gets into the food chain. The prime motivator of such an approach has been the increasing realisation of the significance of the entry, largely through the diet, of varying concentration levels of elements that may be bioavailable for negative interactions in metabolic processes that produce diseases, some of whose diagnoses are still ill-defined (DUA).

It is clear that most DUA's are multifactorial diseases, caused by a complex interplay between genetic factors (polygenic), immunological mediators (trace elements?) and various environmental factors, none of which factors would cause the disease on its own. Based on an extensive literature survey on the subject, it is possible to proffer that trace element dynamics/imbalances in metabolic processes may one day be found to play a far greater role in unravelling the aetiology of DUA than has hitherto been realised.

It is submitted that correlation maps from a completed AGD [analogous to what exists for China (See Wang et al., 2007), England and Wales (See Rawlins et al., 2012), the USA (See Smith et al., 2019), and a few other countries] would, among other applications, enable the depiction of areas where *disease clusters* overlie *anomalous* element distribution (in water, soil or air), and so permit an evidence-based statistical assessment of the magnitude of any geochemical component in the disease causative web.

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